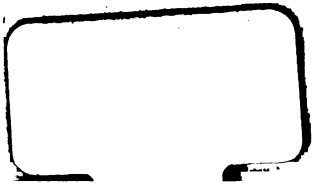
A GUIDE FOR LABORATORY AND FIELD WORK IN ZOÖLOGY

LINVILLE AND KELLY



A GUIDE FOR LABORATORY AND FIELD WORK IN ZOÖLOGY

FOR USE IN CONNECTION WITH

A TEXT-BOOK IN GENERAL ZOÖLOGY

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GINN AND COMPANY

BOSTON · NEW YORK · CHICAGO · LONDON
ATLANTA · DALLAS · COLUMBUS · SAN FRANCISCO

619.11

The Athenæum Press
GINN AND COMPANY · PROPRIETORS · BOSTON · U.S.A.

PREFACE

This book aims to give the student who is beginning the study of zoölogy some directions for laboratory and field work, to which are added a few brief suggestions to the teacher. The function of the directions for laboratory and field work, as has been stated in the preface to the *General Zoölogy*, is to help the pupil to make the best use of his time and to direct him in such a way that he will become more and more independent, and be able to study intelligently without detailed directions. It cannot be too strongly insisted upon that laboratory and field study should precede the use of the text-book. For reasons explained in the preface to the *General Zoölogy*, the directions given beyond are to be regarded merely as suggestive.

The experiments and the observations of the living animal are those which can be easily performed by pupils in the high school, and usually yield definite results. It has been our aim to make the questions on the external structure and the internal anatomy sufficiently detailed to bring out the main features of the gross anatomy of the forms studied, without requiring too minute dissection or insisting upon relatively unimportant measurements. The questions asked are those which an ordinarily intelligent pupil should be able to answer either by observation of the specimen in hand or from his store of knowledge. It ought not to be possible for the pupil to find the answer to a question in the laboratory guide by reference to the pages of a text-book, when he is expected to examine the specimens provided or draw upon past observations; in this fact lies the justification for the complete separation of the text-book from

the directions for laboratory and field study. Many questions are asked in the following pages which require that the pupil consult authorities; usually references are given which we have found useful, though no attempt has been made to give a complete set. Only a very few of the many additional topics which might advantageously be used are mentioned. We have tried to suggest the opportunities for study offered by the great museum collections and the zoölogical gardens in various cities.

Questions have been arranged both in the form of numbered and unnumbered paragraphs in order that teachers may compare the two methods; for better comparison the directions for the study of the living locust and the living frog have been printed in both ways.

It will be noticed that drawings are required of the pupil *after* he has studied the animal, and that emphasis is laid on drawings showing the parts in their proper relation in the animal body; in only a few cases, where certain organs cannot be clearly shown in the body, are they to be separated and made the subject of a distinct drawing.

In the teaching of zoölogy to young pupils two great problems are how to get the pupils in contact with the real object of their study, — the organism in its environment, — and how to arouse their interest in that study so that they will wish to carry it on themselves. The wise teacher will not allow the directions given in this guide to come between him and the pupil he is aiming to instruct. He will modify them to suit his purpose or supplement them with others of his own, knowing that nothing can move like the spoken word and the enthusiasm of personal example.

THE AUTHORS

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A LABORATORY GUIDE

CHAPTERS I–IX. INSECTS

Suggestions to Teachers

The locust has been quite generally found a satisfactory form with which to begin the study of insects. Its structure is sufficiently generalized to make observation of the external structure easy, and the various species are widely distributed and usually abundant in the autumn at a time when many schools begin the study of zoölogy. For the living animal the local species may be used, and the work may be carried on in the field or in the laboratory. Specimens may be collected till quite late in the autumn, in grassy areas in the central and eastern United States, and they will live for some time if kept in a breeding-cage or other receptacle, with a piece of sod. For the external structure, either the Carolina locust (*Dissoteira carolina*), the American migratory locust (*Acridium americanum*), or the lubber locust (*Romalea microptera*) may be used. These are all large species, which may be obtained, if not local to the region, from dealers in natural-history supplies. The authors do not require their pupils to dissect a locust. They have sometimes shown some of the systems of internal organs by dissecting specimens themselves before small groups of pupils, or they have used models or charts, supplemented by blackboard drawings. Very often pupils are found who are able to work out the gross anatomy, and their services may be enlisted for the benefit of other members of the class. The

development of the locust should be studied by means of specimens collected by the pupils or teacher, or obtained of dealers in natural-history supplies.

Drawings to a convenient scale, made after the pupil has examined the organs, serve to fix their appearance in the mind. The pupil should label his drawings with the names of the structures shown. The use of sheets of drawing-paper cut to the same size as the note-paper, and like it bound in tablet form with two holes punched in the side for filing, is recommended. Sheets may be removed and handed in for correction as fast as the work is performed. After correction the sheets may be filed by the pupil in a portfolio cover, with his examination papers and any other work he may do. A convenient size is nine and a half by seven and a half inches.

The square specimen jars manufactured by C. Gundlach & Muller, Ottensen, near Hamburg, Germany, will be found useful in preserving the work of pupils. The jars may be imported duty free by chartered institutions, or through the Kny-Scheerer Company, 225 Fourth Avenue, New York City. A supply of glass plates, some white and some black, should be provided to fit the jars. Throughout the zoölogy course, specimens may be mounted on the plates with gelatin by the pupils, and placed in formalin for comparison with forms to be studied later. The essentials for this work, in addition to those just mentioned, are small porcelain dishes (evaporating-dishes) or other receptacles in which the gelatin may be dissolved in hot water, a glass rod or other object to handle the gelatin when it is of the proper consistency, and some means of heating the water. A convenient way is to furnish each pupil with an alcohol lamp and a ring stand to hold the porcelain dish. The pupil can then dissolve sufficient gelatin in a little water till a paste is formed of such a consistency that it will harden soon after being removed from the dish. No special pains need be taken with the mounting, as excess of gelatin can be scraped off with a knife later.

Little difficulty will be found in mounting most specimens if they can be dried; for specimens whose tissues contain a great deal of water it is sometimes well to dehydrate them by placing them in a strong solution of alcohol for a few moments, immediately after fastening them to the glass plate. This hardens the gelatin more quickly. If it is desired to make a permanent mount, the jar can be closed by use of a cement; if not, the same gelatin used in mounting the specimen can be used to fasten on the cover, which can be removed later, and the jar used for another specimen. It has been found that it does not take a pupil longer to mount a specimen in this way than to make a drawing of it, and, as has been said, the specimens are available for comparison with forms to be studied later. Thus it is extremely helpful for the pupil to have the somites and appendages of the locust in formalin before him when he is working on the external structure of the crayfish. The same statement applies to the study of representatives of the different orders of insects, if time is available for a detailed study of insect morphology. Convenient sizes of jars are six inches wide by eight inches high, six inches wide by six inches high, and four inches wide by six inches high. The jars are about two inches deep.

After the locust some insect which has easily recognizable affinities to it should be studied. The grasshoppers (*Locustidæ*), the crickets (*Gryllidæ*), and the cockroaches (*Blattidæ*) offer abundant material. In the cities it is usually easy to collect a series of cockroaches illustrating the main stages in the development from egg to maturity. The pupils should examine a sufficient number of species to get some idea of what characters reappear in each form studied, and in what ways the members of the various families differ. They should then make tables showing the resemblances and differences in the forms studied, noting the adaptation to varying environments. It would be well to study a representative of one or more of the other orders before insisting on the definition of Orthoptera.

If the school has a general miscellaneous collection of insects, it will be found profitable to divide the orders among the members of the class, requiring each pupil to select from the general collection such insects as he thinks belong to the order which he has been given to study. After selecting the members of his order, each pupil should identify the specimens as well as he can, with whatever references and help the teacher may give. The object of this work, of course, is not so much to teach the names of the species as to give the pupil opportunity for observation and comparison. The method may be varied with large classes of pupils by assigning certain of the large families to different pupils for identification and study.

Field-trips are of the greatest value, and insects offer abundant material for interesting the pupil in the study of insects in the field. The method of field-excursions should be varied, at one time being conducted and directed largely by the teacher; at another time the pupils should have their own special topics for investigation arranged beforehand, and should be required to report upon their observations made without the assistance of the teacher. Trips to a museum of natural history should also be similarly varied. The American Museum of Natural History in New York City has on exhibition not only large collections of the insects of all the different orders, but many special exhibits showing the complete life-history of important species. Where such collections are available they should be utilized to the fullest extent by the teacher.

Several topics for study by pupils both in the field and in a museum will be found in the following pages.

Useful books which will afford other suggestions for study of insects are Comstock's *Insect Life*, Packard's *Our Common Insects*, and Hunter's *Elementary Studies in Insect Life*. Helpful suggestions will also be found in the chapters on insects in French's *Animal Activities* and Needham's *Elementary Lessons in Zoölogy*.

CHAPTERS I AND II

THE LIVING LOCUST

Examine living specimens of the locust both with the naked eye and with the magnifying-glass. Handle freely. Can you suggest any useful function for the "molasses" poured out from the mouth by the locust when handled? It is a bitter-tasting digestive fluid, mixed with partially digested food.

Identify as many of the external organs as possible. Notice the rings (*somites*) of which the body is composed. While the body-covering (*exoskeleton*) is quite generally hardened for protection of the internal organs, there are places where the covering is thin and flexible, thus allowing freedom of motion. Notice the range of motion of the jointed appendages, and the way these are used as the locust moves about. What are the principal places where the exoskeleton is flexible? Are the parts of the locust's body alike in size and shape on either side of a median line, — that is, is the locust bilaterally symmetrical?

What are the colors? Considering the grassy areas which these insects inhabit, is it likely that the colors are of any special advantage to the locust? Why?

Note number of legs and wings. What methods of locomotion has the locust? Try to determine the order in which the legs are moved in walking. What is the function of each pair of legs? Measure the longest leap in number of times the locust's length, measuring from the anterior (front) part of the head to the posterior (hind) tip of the last division of the body (the *abdomen*). From an examination of the structure of the wings, what do you infer as to the function of each pair? If any difficulty is experienced in raising the anterior wings, examine a dead specimen.

The breathing-apertures (*spiracles*) extend along the lateral surfaces (sides) of the locust's body. They appear as round

openings in the body-wall. Some are to be found on the abdomen, others on the division of the locust's body which bears the legs and wings (the *thorax*). Notice the regular movements of the abdominal somites, due to respiration. Count and record the number of the spiracles, and describe their position. Do you notice movements at the mouth of any of the spiracles? If so, to what are they due? Are similar movements to be noticed at the mouth of all spiracles?

Choose specimens which have not been handled, and count the number of respiratory movements per minute. Take the average of several results. Note the temperature of the room for use in the next observation.

Does the number of respiratory movements vary with the temperature? Examine specimens from a Wardian case which has been kept at a higher temperature than the schoolroom, and from a refrigerator, noting temperatures in both cases before removing specimens.

Determine whether the stimulation caused by handling the locusts affects the number of respiratory movements. For this observation use specimens which have been kept at the ordinary temperature of the room.

Study the organs of special sense. On the sides of the head notice the large *compound eyes*. What is their shape? Examine their surface with a magnifying-glass to see the divisions (*facets*) of which each is composed. Just anterior to each compound eye find a round spot, an *ocellus*, or simple eye. Find another ocellus on the head. Describe the position of the ocelli. Have you any experimental evidence that the locust can see?

Notice the feelers (*antennæ*). Describe their position and structure. Try touching the antennæ with a pencil or similar object. Result? Try bringing a glass rod which has been dipped in cologne or ammonia near the antennæ, but without touching them. Can the locust smell? What do you consider to be the

function or functions of the antennæ? On the lateral surfaces of the first abdominal somite are oval spots, the external indications of the *ears* of the locust. Have you any experimental evidence that the locust can hear?

Feed a locust by placing the tip of a grass-blade or a bit of clover or lettuce in its mouth. Can you suggest an experiment to test whether or not the locust can taste? Describe briefly the method of feeding. The names of the mouth-parts will be found in the following outline for the study of the external structure of the locust.

EXTERNAL STRUCTURE OF THE LOCUST

The head. The antennæ, compound eyes, and ocelli have already been referred to in the outline for the study of the living locust.

Examine the mouth-parts. The anterior boundary of the mouth is a movable flap, the *labrum,* or upper lip. Raise it, or cut it off, exposing the hard, toothed *mandibles,* or jaws, each composed of a single piece. After prying with the forceps note how the mandibles move. Posterior to the mandibles are two sets of jointed organs, the *first* and *second maxillæ.* It will be easier to examine the latter first. The bases of the second maxillæ are united, making a flap called the *labium,* or lower lip, which forms the posterior boundary of the mouth. Two short "feelers," or *palpi,* are attached to the second maxillæ. After examination the second maxillæ may be removed with the forceps as a single piece. Save for drawing. The first maxillæ are a pair of jointed organs, each composed of two separate parts borne on a common base, and with a several-jointed *palpus* projecting from the outer side. Between the mandibles, and arising from the inner side of the labium, is a short, brown, tongue-like organ, the *hypopharynx.* Recalling what you saw of the action of the mouth-parts in your study

of the living locust, taken in connection with what you have observed of the structure of the organs, discuss briefly the function of each part. Make a drawing of the mouth-organs (magnified four times), as seen from below, placing them in their proper position as removed from the specimen, thus:

* labrum
* * mandibles
* * first maxillæ
* hypopharynx
* second maxillæ

If there is any difficulty in getting the organs properly placed, choose another specimen. Mark the drawing "Mouth-Organs of Locust × 4." Label each part.

The thorax. The first division of the thorax is separate from the others, and is called the *prothorax;* the second division is the *mesothorax;* the third, the *metathorax.* A line (*suture*) separates the mesothorax from the metathorax. What *jointed* appendages does each division of the thorax bear? Compare the anterior and posterior wings as to size, shape, and texture.

For study of the chief segments of the legs, choose the second pair of legs. The principal divisions of the leg are the thick *femur* and the spiny *tibia.* The leg ends in a series of short segments forming the *tarsus,* or foot, the last segment of which bears two *claws* with a pad, the *pulvillus,* between them.

Make a drawing of one of the second pair of legs (× 3), viewed from the outside. Mark the drawing properly and label the segments mentioned above. Examine the anterior and posterior legs, and note whether the segments above mentioned are to be found in them. What segments are most modified in the last pair of legs?

The abdomen. The ears of the locust have already been referred to. The end of the abdomen of the female is more tapering than in the male, and is furnished with two pairs of

blunt spines, the egg-laying instrument, or *ovipositor*. Two pairs of small conical processes, the *cerci*, project from the lateral surfaces near the end of the abdomen in both sexes. The cerci represent reduced appendages. Decide whether your specimen is a male or female, and correctly mark the drawing required below.

Make a drawing (× 2) of the locust as seen from the left lateral surface, showing as many of the parts referred to as possible. Properly label the drawing and mark the names of all the parts.

EXTERNAL STRUCTURE OF THE LOCUST

(*Alternative method with numbered paragraphs*)

NOTE. The locust's body has three natural divisions, or regions, — *head*, *thorax*, and *abdomen*.

1. Where are the lines of separation between these regions?
2. How many pairs of *legs* has the locust?
   To which region are they attached?
3. To which region are the *wings* attached?
   Spread out the wings and tell what differences you observe between the two pairs.
4. How would you describe the material which forms the covering of the body, the legs, and the wings? (The name of this substance is *chitin*, pronounced *ki'tin*.)

   NOTE. The abdomen, as well as the head and thorax, is divided into several ring-like structures called *somites*.
5. How many of these somites can you find in the abdomen?
6. Describe the position and the structure of the *antennæ* (feelers).
7. In what direction can the locust probably see with its large (called *compound*) eyes?
8. State the exact position of the three minute (*simple*) eyes.
9. How does the structure of the mouth-parts suggest their use?

NOTE. The *ear* is a noticeable cavity on the first abdominal somite.

10. What do you see at the bottom of the cavity, and what is the probable use of this structure?

NOTE. The locust breathes through very small openings, or *spiracles*, on the sides of the body.

11. Locate and give the number of spiracles on each somite of the abdomen; describe the spiracles of the thorax.

NOTE. The female has four hard structures at the end of the abdomen, which she uses for making a hole in the ground for her eggs. These four structures make up the *ovipositor*.

12. Find a male and state what you observe in the corresponding part of the body.

How do the male and female differ in the shape of the tip of the abdomen?

DRAWINGS

I. General view of left side × 2. (Raise the wings slightly.)
II. Dorsal view × 2. (Spread out the wings on the left side.) Label all parts shown.

GRASSHOPPERS

Make a study in the field of grasshoppers, which may be distinguished from locusts by their much longer antennæ. An insect net will be found almost indispensable. For killing grasshoppers, use a cynanide bottle. Preserve several individuals of each species collected. They may be mounted by pinning through the prothorax with an insect pin. Push the insect two thirds of the way up the pin. Place a small piece of stiff paper beneath, if necessary, to hold the legs in a horizontal position till they dry. Specimens may also be preserved in alcohol or formalin. Use small, wide-mouth bottles; place only one species in a bottle. Study as many as possible of the following topics.

What is the particular character of the environment in which grasshoppers live? Among what vegetation? In dry or wet

areas, or both? On what part of the vegetation are they to be found? Have they any special place of refuge? Are grasshoppers nocturnal or diurnal in their habits?

In what ways are grasshoppers adapted to their environment? How is the general body-form adapted to their life? Is the color protective? Consider the number and character of the jointed appendages and how they are used. What methods of locomotion have grasshoppers? Study and report upon the methods of locomotion.

Try to determine what animals feed upon grasshoppers. If possible, make a list of the grasshoppers' enemies, explaining the mode of attack of each kind. What means have grasshoppers of evading each particular enemy? Have they any special means of defense? On what sense do grasshoppers seem to depend to notify them of the presence of an enemy?

On what substances do grasshoppers feed? Study and report upon their method of feeding.

Do grasshoppers grow by an increase of size merely, or is their growth accompanied by marked change of form, or metamorphosis? You may be able to find individuals in different stages of growth, which will enable you to answer these questions; if so, preserve them.

Are grasshoppers social or solitary in their habits? Do you notice any cases of coöperation of several individuals for any common purpose? Do you notice any evidences of intelligence?

How many different kinds or species of grasshoppers have you seen in the course of your study? What characters do you rely upon to separate one species from another? Describe each species briefly. Are the different species all found in the same environment?

Examine as large a series as possible of specimens of the commonest species you have been able to find. Outside of the differences which mark their stages of growth, are all the individuals exactly alike? If not, describe the variations which occur.

Do you notice any other characteristic, in addition to the greater length of antennæ, which you could use to separate grasshoppers from locusts? Have you collected any insects which are evidently related to locusts and grasshoppers, but which seem to differ from the members of both groups?

CRICKETS

Collect crickets from beneath sticks and stones in fields and other places. How does their environment differ from the environment of locusts and grasshoppers? How many different kinds of crickets have you been able to collect? Have you collected any immature specimens? How can you tell the young from the adult? Do you know of any crickets being found in houses? If so, try to obtain specimens of these for comparison with specimens collected in the fields. Are they the same kind?

Try to keep some crickets in order to determine just how the familiar chirp is produced. Are crickets nocturnal or diurnal insects? Under what conditions is the noise produced? If possible, make a sketch of a cricket while it is chirping, and describe what you observe.

Examine one of the crickets as you did the locust, identifying the organs mentioned in that study, as far as you are able to find them. Some suggestions for the observation of structures which you might not be able to recognize otherwise are given in the following paragraph.

The *ears* of the cricket will be found in the front tibiæ. The two long, slender projections from the abdomen, near its posterior end, are the *stylets*. The elongate structure at the tip of the abdomen (in the female) is the *ovipositor*. Look on the under surface of the first pair of wings of the male for a thickened vein running diagonally near the anterior end, and bearing little teeth-like structures, the whole forming a "rasp" or "file." On the other anterior wing is a thickened vein, the "scraper."

Write a short account of the principal resemblances and differences between crickets and locusts, keeping in mind the following questions. What differences have you noticed in the habits of the two groups of insects? Considering the environment and mode of life of crickets, do you think they are protectively colored? Do you notice any adaptation in the form of the body to the environment?

Do the mouth-parts of crickets and locusts seem to be formed on the same plan? What differences do you notice in the antennæ? Are there any important differences in the legs? What differences are to be noted in the wings? Do female crickets possess the sound-producing organ? What structures in locusts occupy a similar position to the stylets of crickets? Can you suggest any function for the stylets? Can you explain the differences in antennæ, legs, and wings (or any other differences in the external structure of organs) by reference to the mode of life of crickets? Do crickets seem to be more closely related to locusts or to grasshoppers? Why?

COCKROACHES

Collect specimens of cockroaches from warm, moist places in city houses, from beneath boards in gardens or bark of stumps in fields, or from other places which you know them to frequent.

Compare their external structure and general color with that of locusts, grasshoppers, and crickets. What modifications do you notice in the shape of the body? Have cockroaches wings? How do the legs differ from the legs of locusts, crickets, and grasshoppers? Can you explain the differences you have noticed by reference to the mode of life of cockroaches? Do you know any enemies of cockroaches?

How many different kinds of cockroaches did you succeed in capturing? How do you distinguish one kind from another? Did you obtain specimens of one kind at different ages? What

differences are there between the young and adult? Did you capture any female specimens with egg-cases attached to the abdomen?

What is the food of cockroaches? In what estimation are cockroaches held by people? Why? What is the economic importance of cockroaches?

Make a series of drawings illustrating the life-history of one kind of cockroach.

Additional Topics for Study

Make a collection of Orthoptera, classifying them by means of the following references:

J. H. Comstock and Anna Botsford Comstock, *Manual for the Study of Insects.*

L. O. Howard, *The Insect Book.*

C. H. Fernald, *Orthoptera of New England.*

The Riverside Natural History (formerly the *Standard*), Vol. II.

The Cambridge Natural History, Vol. V, Part I.

Make a special study at a museum of natural history of cases of protective and aggressive resemblance in Orthoptera.

Look up the habits of migratory locusts of the world in Chapters III and IV of the *Second Annual Report of the United States Entomological Commission*, On the Rocky Mountain Locust.

For the habits of migratory locusts in the United States, consult *Bulletin No. 25* (old series), United States Department of Agriculture, Division of Entomology, by C. V. Riley.

Look up references to the house-cricket in English literature.

CHAPTER III

DRAGON-FLIES

Visit a place where dragon-flies are to be found. Note the character of their habitat, and what they are doing. Study their flight. If possible, time the speed of their flight. In what

places do they alight? At what time of day are they most numerous? Are they most abundant on bright, sunshiny days or on cloudy days? Notice whether the dragon-flies observed are all apparently of the same species. If not, what differences in structure and habits can you discover? If possible, find a different locality where these insects may be found, and discover whether the same kinds of dragon-flies are to be found there.

If possible, collect specimens of each species observed, and study the external structure of one species, following the same general plan suggested for the locust. Try to interpret the structure by reference to what you have observed of the living dragon-fly. Make a drawing (× 2), labeling the parts shown.

Dredge for dragon-fly young in some pond or pool. Look for some of the cast nymph-skins on stones and sticks or on vegetation near the water. The young of dragon-flies are flattened, brownish nymphs with a wide, flat head and thorax and greatly enlarged second maxillæ, which cover the mouth like a mask. The nymphs may be kept alive in an aquarium. Study their structure and activities. What means of protection have the nymphs? Observe the effect of passing a stream of carmine, or other colored solution, from a pipette close to the anal region. Draw the nymph (× 2).

CHAPTER IV

SQUASH-BUGS

Collect squash-bugs of all sizes from the leaves of squash-vines or pumpkin-vines. Are they to be found on other vegetation? Notice the effect of these bugs on the vegetation. How do they feed? How do the young differ from the adult? What special means of protection have squash-bugs? Compare the external structure, especially of wings and mouth-parts, with the structure of the same organs in other insects studied. Draw a nymph and an imago (× 2), labeling the parts.

THE CICADA

Study the external structure of the cicada, comparing it with that of the other insects studied. Compare the fore wings of the cicada with those of the squash-bug. Examine the mouth-parts. To what insect does the cicada seem in this respect most closely allied? On the ventral surface at the base of the abdomen of the male is a drum, or sound-producing organ. Decide whether your specimen is a male or female.

Examine the cast nymph-skin. What modifications of external organs have occurred in the change from nymph to imago? Draw nymph-skin and imago, natural size, labeling the parts.

For further information on the cicada, consult *Bulletin No. 14* (new series), United States Department of Agriculture, Division of Entomology, by C. L. Marlatt.

ADDITIONAL TOPICS FOR STUDY

Study the structure and habits of the back-swimmers and the water-boatmen, using specimens from the school aquarium.

For information as to important products of the scale-insects (*Coccidæ*), consult *The Cambridge Natural History*, Vol. V, Part II.

For information on the San José scale-insect, consult *Bulletin No. 3* (new series), United States Department of Agriculture, Division of Entomology, by L. O. Howard and C. L. Marlatt; and *Bulletin No. 12* (new series), United States Department of Agriculture, Division of Entomology, by L. O. Howard.

For further information on plant-lice, consult *Bulletin No. 9* (technical series), United States Department of Agriculture, Division of Entomology, by Theo. Pergande; also *Life-Histories of American Insects*, The Hibernation of Aphides, by C. M. Weed.

For the life-history and economic importance of the chinch-bug, consult *Bulletin No. 17* (old series), United States Department of Agriculture, Division of Entomology, by L. O. Howard; and *Bulletin No. 15* (new series), United States Department of Agriculture, Division of Entomology, by F. M. Webster.

CHAPTER V

BEETLES

Collect as many species of beetles as possible. They will be found in every variety of situation. Some are found under sticks or stones. Many species can be obtained from the flowers and leaves of plants by holding an umbrella wrong side up and shaking the branches above by striking them with a stick. Large numbers live in the water or skim over its surface. Decaying animal or vegetable matter will afford many species. Place a few pieces of fresh meat or fish in a wide-mouth bottle, and sink in the ground to the level of the mouth. Examine daily. Piles of wood and recently cut timber should be examined. Collect the beetles in a cyanide bottle, or a bottle in which small pieces of wood, like broken matches, have been saturated with benzine.

Classify your captures as well as you can by placing together those which seem to have similar characters.

Some of the largest and commonest families are the ground-beetles (*Carabidæ*), the lamellicorns (*Scarabæidæ*), the leaf-beetles (*Chrysomelidæ*), the long-horn borers (*Cerambycidæ*), and the weevils (*Curculionidæ*). Use the following books of reference:

J. H. Comstock and Anna Botsford Comstock, *Manual for the Study of Insects.*

The Riverside Natural History (formerly the *Standard*), Vol. II.

The Cambridge Natural History, Vol. V, Part II.

STRUCTURE OF A BEETLE

Study some large beetle, comparing its external structure with that of the other insects studied. Identify the mouth-parts. How do the wings differ from the wings of the locust?

Make a drawing (× 2), labeling parts shown.

THE MEAL-WORM

Examine the meal-worm to get some idea of the characteristics of the larva of a beetle.

Describe the body-covering. What clearly marked regions can you distinguish in the body? How does the larva progress?

Examine and describe the organs of sight, and of touch, and the mouth-parts.

Make a drawing (× 2).

Additional Topics for Study

Consult an encyclopedia, or other book of reference, for a description of the sacred beetle of the Egyptians, its habits, and the part it played in the symbolism of the people.

Consult Part II of *The Cambridge Natural History*, Vol. V, for the life-history of the blister-beetles.

For the habits of a leaf-beetle, consult Cold Spring Harbor Monographs, IV, *The Life-History of the Case-Bearers:* I. *Chlamys plicata*, by Ella Marion Briggs.

For information on the Mexican cotton-boll weevil, consult *Bulletin No. 45*, United States Department of Agriculture, Division of Entomology, by W. D. Hunter and W. E. Hinds; also *Farmers' Bulletin No. 130*, United States Department of Agriculture, by Frederick W. Mally.

CHAPTER VI

BUTTERFLIES

In favorable weather make a study of butterflies in the field, following the same general plan of study already suggested for grasshoppers in the field.

Note particularly the character of the flight of butterflies and the manner of alighting. How are the wings held when butterflies are resting?

Take note of the kinds of flowers, if any, visited by butterflies. What is the object of their visits to flowers?

Collect as many different species of butterflies as possible. Do certain species visit particular flowers? What is the most favorable time of day to collect butterflies? Do you find any butterflies which differ widely from the others in the position of the wings when at rest?

Examine a butterfly closely to study its external parts, as used in life. Handle with care in order not to rub off the fine scales with which the wings are covered.

THE CABBAGE-BUTTERFLY

Visit a cabbage-patch to study the habits of the cabbage-butterfly. It may be recognized by its yellowish color, paler above, and by the brownish or black tips of the fore wings. The female has two round black spots near the outer margin of the fore wings; the male has only one spot in the same region. Collect several specimens for identification. Describe briefly. Do you notice any other sexual difference besides that mentioned above? Has either sex any odor? Are all the specimens of the same sex similar in size and color markings? If not, mention the most striking differences. What are the cabbage-butterflies doing? Are any other butterflies abundant?

Try to find the eggs, which are light yellow in color and are usually attached singly to the under side of the cabbage-leaves. Describe briefly. Take home some leaves with eggs for observation under the microscope. Make a drawing of the egg, stating magnification used. If possible, keep some eggs till they hatch.

Find and describe the larva. It is a green caterpillar with a narrow, lemon-yellow dorsal band. When full grown it is about four fifths of an inch long. Examine larvæ of different sizes. Do they differ in other respects than size as they grow older? Describe the two sorts of legs. Study and describe the method

of locomotion. Observe and report upon the method of feeding. Note the spinning of silk by the larva. What is the object of this? If possible, visit the cabbage-patch at different hours of the day, on cold and warm days, on dry and wet days, and on cloudy as well as sunshiny days, and report upon the time of feeding and the effect of different weather conditions. Is the larva protectively colored? Have you observed any enemies?

Collect larvæ and place in a breeding-cage or other receptacle. Keep in a light and well-ventilated room, supplying them with fresh cabbage-leaves daily. Study their growth. Make drawings every three days.

When the larvæ pupate, examine and describe the pupa, its color, size, shape, and method of attachment. In what ways does it differ from the larva? Make a drawing.

If possible, keep the pupæ till the imagoes emerge. Report on the time and method of emergence. How does the imago differ from the larva? Some of the pupæ may produce not cabbage-butterflies but small ichneumon-flies, the eggs of which were laid in the skin of the larvæ. If these parasities are observed, study their external structure with a magnifying-glass or with a low power of the compound microscope. Try to determine how those pupæ which produce ichneumon-flies may be distinguished from those not parasitized.

Arrange your notes in the form of a short life-history of the species, using drawings throughout to illustrate your work.

THE MONARCH, OR MILKWEED-BUTTERFLY

Study the external structure of the milkweed-butterfly after the general plan already suggested for the locust. Pay particular attention to the mouth-parts.

Make a cross-section of the tongue-like proboscis and examine under the compound microscope. Examine some of the scales from the wings with the microscope. Make a drawing of each object, stating magnification used. Are the scales colored?

Make a drawing of the butterfly (× 2), labeling parts shown.

Collect the larvæ or pupæ in late fall, and study the transformations of the insect. For details of the life-history which you are unable to work out, consult Scudder's *Guide to Our Common Butterflies*, or other reference.

CATERPILLARS

Look about on the leaves of shrubs and in protected places till you find some caterpillars. Before disturbing them notice what they are doing. Make a sketch of the way they look on the leaf or whatever object they may happen to rest on.

If the caterpillars are feeding, study the way they feed. Note the amount of leaf-material eaten in fifteen minutes. Do you see evidences of the work of caterpillars on the vegetation?

Notice the body-covering of the caterpillar. What means of protection has the caterpillar? Into how many somites is the body divided? The caterpillar has two kinds of legs: the first set are true legs; the second set are false or prop-legs. Describe the number and position of each kind.

Are spiracles apparent? If so, describe their number and arrangement.

If possible, keep some of the caterpillars till they pass into the pupal stage, feeding them with the leaves of the plant on which you found them. What changes do the caterpillars undergo in the course of time they are under observation? Describe the pupa.

In what ways does the caterpillar differ from the imago? How does it resemble the imago? Draw the caterpillar, natural size, labeling parts.

COLLECTION OF PUPÆ IN WINTER

In the winter collect pupæ of butterflies and moths. Some pupæ are protected by a closely knit cocoon of silk, others by a cocoon of loose texture, while still others are naked. Look on the branches of shrubs along roadsides or paths, on the under

side of fence-rails, or beneath boards and stones on the ground. Collect as many different kinds as possible, keeping each kind separate in small boxes, with bark or moss or other portion of their natural environment. Keep notes as to where each kind was found. Bring to school for study and identification. If possible, keep them alive in breeding-cages till the insects emerge.

MOTH ESCAPING FROM COCOON

Study a moth escaping from its cocoon. What changes occur at the time? How long does it take the moth to emerge? In what condition does it emerge? How does it escape from the cocoon? Does the moth increase in size after the tissues have hardened and the colors have appeared?

The female moth will often lay eggs soon after escaping from the cocoon. If possible, obtain the eggs, and examine them with the compound microscope. Describe.

COCOON OF A MOTH

Examine the cocoon furnished. Describe its shape, color, and texture.

With sharp scissors cut the cocoon open, being careful not to cut into the pupa. Describe the color and texture of the silk of the interior. What is found in the cocoon besides the pupa?

Describe the pupa. Identify as many as possible of the external organs of the imago.

Examine another cocoon from which the moth has escaped. What is left? How did the moth escape? Draw the cocoon and pupa, natural size, labeling parts.

Additional Topics for Study

Examine a moth and a butterfly, and describe the points of structure in which they differ. How do they resemble each other? Note also any differences with which you are familiar in the life-history of members of the two groups.

Find a nest of a tent-caterpillar, and make a study of it and its inhabitants. What vegetation do these insects infest? Describe the nest and its position. Describe one of the larvæ found in it. When do the larvæ feed? Watch the nest for a week or more till the caterpillars transform. How do they pupate? Can you suggest a remedy for the attack of these insects? Look up further details of the life-history and the appearance of the imago in the references given for the study of insects.

For the gipsy-moth, consult *Bulletin No. 11* (new series), United States Department of Agriculture, Division of Entomology; also *Report to the Massachusetts State Board of Agriculture* (1896), The Gypsy Moth, by Edward H. Forbush and Charles H. Fernald.

Consult an encyclopedia or other book of reference for the economic importance of the silkworm-moth and the methods of silk-culture. What progress has silk-culture made in the United States?

CHAPTER VII

THE HOUSE-FLY

Catch a few house-flies at home, and study their external structure, comparing it with the structure of the locust. Make a drawing (× 4), labeling parts.

Capture some flies, and place them beneath a clear glass vessel. Within a day or so put a piece of granulated sugar beneath the glass. Try also moistened sugar, molasses, and vinegar. By which substance are the flies most attracted? By what sense does the fly find its food? Observe and report upon the method of feeding.

Examine and describe the structure of the feet under the compound microscope. For what purposes besides walking does the fly use its first pair of legs?

Try holding the fly by its body, and note the sound produced. Hold it by the wings, and see if the sound is still produced.

Additional Topics for Study

For information concerning the Hessian fly in the United States, consult *Bulletin No. 16* (new series), United States Department of Agriculture, Division of Entomology, by Herbert Osborn.

For the relations which exist between Diptera and disease, consult some of the following references:

Surgeon-General George M. Sternberg, U.S.A., Malaria, *Popular Science Monthly*, Vol. LVIII, No. 4, February, 1901.

Dr. Gary N. Calkins, The Malaria Germ and Allied Forms of Sporozoa, *Popular Science Monthly*, Vol. LIX, No. 2, June, 1901.

Surgeon-General George M. Sternberg, U.S.A., The Transmission of Yellow Fever by Mosquitoes, *Popular Science Monthly*, Vol. LIX, No. 3, July, 1901.

Dr. L. O. Howard, Flies and Typhoid Fever, *Popular Science Monthly*, Vol. LVIII, No. 3, January, 1901.

Symposium on Yellow Fever and Other Insect-Borne Diseases: I. *Science*, Vol. XXIII, No. 584, March 9, 1906, p. 366; II. *Science*, Vol. XXIII, No. 585, March 16, 1906, p. 401.

For the habits of mosquitoes, consult *Bulletin No. 25* (new series), United States Department of Agriculture, Division of Entomology, by L. O. Howard.

CHAPTER VIII

BUMBLEBEES

Visit a field of blossoming clover or other place where bumblebees are to be found. Study these insects after the general plan suggested for grasshoppers. Determine what the insects are collecting from the flowers. Follow one bee to determine whether it visits a single species of flower or several different species. Note the character of the bumblebees' flight. Compare it with the flight of other insects you have studied. Catch a bumblebee in a net, and determine whether the pitch of the humming sound is changed in captivity.

Study the external structure of the bumblebee, comparing it with the other insects studied. Notice the hooks on the hind wings by which the hind wings are fastened to the front wings in flight. Examine particularly the "pollen-baskets" on the outer side of the hind tibiæ. Examine the sting. Make a drawing of the bumblebee (× 2), labeling the parts shown.

MUD-WASPS

Find a place where mud-wasps are at work, and study their method of nest-making. If possible, discover the source of the material used. Notice how the material is worked. How do wasps produce the sound which you hear? While the wasp is away remove a portion of the nest, and examine it. If a cell has been sealed, discover what its contents are. If possible, find a cell with a larva or pupa in it. If found, describe them. How may you distinguish the mud-wasp from other species of wasps?

STUDY OF AN ANT-COLONY

Overturn a few flat stones until you find an ant-colony. (Always turn the stone back again when you are through, for the possible benefit of other observers.)

At first you may find several hundred workers busily engaged in carrying away some small white and yellow objects. The small white objects are the larvæ of the ants, and the larger things, inclosed in tough yellow sacs, are the pupæ. Try to find out exactly how the older ants take hold of these, and what they do with them.

Notice whether the ants work with a plan, whether they seem to know where they are going, and how long it is before all have disappeared.

Determine whether all the ants seen are alike in size and shape.

Additional Topics for Study

Study the structure of the nest of one of the paper-making wasps.

Look up in an encyclopedia or other book of reference some of the remarkable instincts of ants.

For the habits and care of the honey-bee, consult *Bulletin No. 1* (new series), United States Department of Agriculture, Division of Entomology, by Frank Benton.

Consult some of the following references for instinct and intelligence in the Hymenoptera:

Dr. Minnie Marie Enteman, On the Behavior of the Social Wasps, *Popular Science Monthly*, Vol. LXI, No. 4, August, 1902.

George W. and Elizabeth G. Peckham, *Wasps, Solitary and Social.*

Lord Avebury (Sir John Lubbock), *Ants, Bees, and Wasps.*

Dr. William Morton Wheeler, The Queen Ant as a Psychological Study, *Popular Science Monthly*, Vol. LXVIII, No. 4, April, 1906.

CHAPTER IX

A REVIEW EXERCISE ON INSECTS

What are the characters in which you have found all insects to agree?

Arrange your paper as below, and fill out the characters of the different orders of insects.

	Thysanura	Orthoptera	Plectoptera	Odonata	Hemiptera	Coleoptera	Lepidoptera	Diptera	Hymenoptera
Mouth-parts									
Wings									
Legs									
Development									

Additional Topics for Study

Write a paper on the economic importance of insects, discussing each of the large orders with reference to injurious and beneficial forms.

Write a paper on protective resemblance in the class of insects, giving examples.

Write a paper on (*a*) the adaptations of insects to life in the air, (*b*) adaptations to life in the water, (*c*) adaptations to a burrowing life.

For the habits of white ants, consult *Smithsonian Report* for 1901, Observations on Termites or White Ants, by G. D. Haviland.

For questions relating to color of insects, consult *Animal Coloration*, by Frank E. Beddard; also *The Colors of Animals, their Meaning and Uses*, by E. B. Poulton.

For the relations between flowers and insects, consult some of the following references:

George Henslow, *The Origin of Floral Structures through the Action of Insects and Other Agencies.*

William Hamilton Gibson, *A Few Native Orchids and their Insect Sponsors.*

H. Muller, *The Fertilization of Flowers.*

Charles Darwin, *The Various Contrivances by which Orchids are fertilized by Insects.*

For instinct and intelligence in insects, read *The Senses, Instincts, and Intelligence of Animals, with Special Reference to Insects*, by Sir John Lubbock. See also references under the general heading of Instinct and Intelligence in the Animal Kingdom, Chapters XXX and XXXI.

Read the article on National Control of Introduced Insect Pests, by Professor E. Dwight Sanderson, in *Popular Science Monthly*, Vol. LXVIII, No. 5, May, 1906.

Describe the activities of the United States Department of Agriculture, Division of Entomology, as shown in the latest report of the Division.

For information concerning the agricultural experiment stations in the United States, consult recent reports of their work published by the Department of Agriculture.

Make a special study of the insect enemies of some garden plant. Consult some of the following references:

F. H. Chittenden, Some Insects Injurious to Orchard and Garden Crops, *Bulletin No. 19* (new series), United States Department of Agriculture, Division of Entomology.

F. H. Chittenden, Some Insects Injurious to Vegetable Crops, *Bulletin No. 33* (new series), United States Department of Agriculture, Division of Entomology.

C. L. Marlatt, The Principal Insect Enemies of the Grape, *Farmers' Bulletin No. 70*, United States Department of Agriculture.

Make a study of insects which infest houses. For identification and information, consult *Bulletin No. 4* (new series), United States Department of Agriculture, Division of Entomology, The Principal Household Insects of the United States, by L. O. Howard and C. L. Marlatt.

For information concerning insects affecting domestic animals, consult *Bulletin No. 5* (new series), United States Department of Agriculture, Division of Entomology, by Herbert Osborn.

CHAPTER X

THE DOCTRINE OF EVOLUTION

For a simple general account of evolution in the animal kingdom, read either *A Primer of Darwinism and Organic Evolution*, by J. Y. Bergen and F. D. Bergen, or *A Primer of Evolution*, by Edward Clodd.

For further study of some of the factors in evolution, consult some of the following references:

Dr. J. A. Allen, The Evolution of Species through Climatic Conditions, *Science*, Vol. XXII, No. 569, November 24, 1905, p. 661.

President David Starr Jordan, The Origin of Species through Isolation, *Science*, Vol. XXII, No. 566, November 3, 1905, p. 545.

Professors W. E. Castle, Edwin E. Conklin, Thomas Dwight, L. H. Bailey, William Morton Wheeler, and Dr. D. T. MacDougal, special articles on the Mutation Theory of Organic Evolution, *Science*, Vol. XXI, No. 536, April 7, 1905, p. 528.

Charles A. White, The Mutation Theory of Professor de Vries, *Report of Smithsonian Institution* for 1901.

T. H. Morgan, The Origin of Species through Selection contrasted with their Origin through the Appearance of Definite Variations, *Popular Science Monthly*, May, 1905.

For the history of the evolution idea, read *From the Greeks to Darwin*, by Professor H. K. Osborn; *The Study of Animal Life*, Chapter XVIII, by J. Arthur Thomson; *Pioneers of Evolution*, by Edward Clodd.

For further information on evolution, read *Organic Evolution*, by Professor M. M. Metcalf; *The Study of Animal Life*, Chapters III, XVII, and XIX, by J. Arthur Thomson.

Read the two articles by Charles Darwin and Alfred Russel Wallace, presented to the Linnæan Society of London at the same time, and printed in the journal of the society. These will be found reprinted in the *Popular Science Monthly*, Vol. LX, No. 1, November, 1901.

CHAPTER XI. ARACHNIDS AND MYRIAPODS

WEB OF THE GARDEN-SPIDER

Search about till you find the web of a garden-spider in perfect or nearly perfect condition. If the spider is not visible, examine the leaves near which the web is attached till you find it.

Make a study of the web. What is its shape? What is its plan of structure? Note its points of attachment. Consider the extent to which the web is adapted to its purpose. Where does the spider usually rest? Make a diagram of the web, natural size.

Throw a fly or other small insect into the web, and if the insect is seized, study the spider's method of securing food. If possible, secure some large species of wasp, and note the spider's behavior when this insect is introduced into the web.

Make what study you can of the external structure of the spider, comparing it with the structure of the locust or other insect.

If the spider can be removed and kept in a large glass jar or a breeding-cage, the building and repair of the web may be studied. Devise an experiment to test the spider's sense of smell. At what distance can the spider see? Can the spider hear?

EXTERNAL STRUCTURE OF THE SPIDER

Note the division of the body into two parts, — the *cephalothorax* and the *abdomen.*

Examine, identify, and describe the mouth-parts. How many *eyes* has the spider, and how are they arranged? Are the eyes simple or compound?

How many *legs* has the spider? Describe them.

At the posterior end of the abdomen find the *spinnerets.* How many are there?

Near the base of the abdomen in the median line is the external opening of the *reproductive organs.* On either side of this opening are the *lung-sacs* containing plates into which blood flows and is then aërated.

In what ways does the spider resemble an insect? How does it differ from an insect?

Draw the spider as seen from the ventral surface (× 2), labeling the parts shown.

Draw the mouth-parts (× 2).

THE CENTIPED AND THE MILLEPED

Collect specimens of the common centiped (*Lithobius*) from beneath the bark of stumps, under leaves in the woods, or beneath sticks or stones in fields and near gardens. Keep some specimens alive, and report on their activities and external

structure. Compare the external structure with that of the spider and an insect.

Several species of millepeds (*Julus* and *Spirobolus*) may be found in situations similar to those of the centipeds. The millepeds are more cylindrical forms, which usually coil themselves when disturbed, instead of hurrying away in search of a place of safety. Compare the external structure of the milleped and the centiped. In what details of structure do they resemble each other? How do they differ in structure?

Additional Topics for Study

Collect some of the large brown running spiders from beneath sticks, boards, and stones. Keep in a suitable receptacle, with some object under which they may retreat. Keep supplied with various insects for food. Study their structure and activities.

Look up the habits of the jumping-spider.

CHAPTERS XII AND XIII. CRUSTACEANS

THE CRAYFISH

Suggestions to Teachers

Crayfishes can be obtained all the year round in the markets of the large cities. They may be kept in damp, loose hay, but should not be placed in numbers in shallow water. One or two may be kept in an aquarium indefinitely, where they can subsist on water-plants. For observing the activities of crayfishes in laboratory classes, a white-lined tray about two inches deep and ten inches long, partly filled with water, will retain one specimen for the use of two pupils.

Three sets of questions are offered on the external structure of the crayfish and its activities. Those schools which prefer to

study the structure and the activities separately may select the sets accordingly.

Besides the references given under the "Additional Topics for Study" on p. 38, Huxley's *Crayfish* and Morgan's *Animal Sketches* are generally available.

MORPHOLOGY AND ACTIVITIES

1. Describe the coloration of the crayfish.
2. Give your idea of any advantage the colors might be to the animal as it moves about on the bottom of ponds, rivers, or brooks.
3. Give evidence bearing on the plan of symmetry of this animal, to show whether it is radial or bilateral.
4. What are the structural characters of the anterior half of the body (the *cephalothorax*), and of the posterior half (the *abdomen*)?
5. How many *somites* are there in the abdomen anterior to the tail?
6. How many pairs of appendages are there which, because of their customary function, we could call *walking-legs?*
7. What differences of structure do you observe between these walking-legs?
8. What resemblances are to be observed when you compare the *chelipeds* (the large claws) and the nearest pair of walking-legs?
9. To what extent is there regularity of movement in the walking-legs?
10. Give a full account of whatever adaptations you see in the structure of the chelipeds.
11. How many *antennæ* do you find?
12. Plan some test by which you can determine the use of the antennæ. (Tell what you did.)
13. State at least two adaptations in the structure and movements of the *eyes.*

14. What do you suppose are the uses of the hard shell or crust on the outside of the crayfish?
15. What appendages are found on the abdomen, and what are their uses as discovered by observation? (The lateral parts of the tail may be considered as abdominal appendages.)

NOTE. One way of knowing the male from the female is by noticing the difference between the first pair of abdominal appendages. In the males they are long and heavy; in the females, very small and thread-like. The sexual cells (eggs and spermatozoa) emerge from the body by an opening on the basal segments of certain of the walking-legs.

16. Find these openings on a male and also on a female.
17. Test by experiment to learn how a crayfish gets on its feet when overturned.
18. Discover how the crayfish might escape from an enemy most quickly.
19. What adaptations are evident in the parts of the body used when this animal is trying to escape by its most rapid method?
20. Ascertain in a prepared specimen the structure and attachment of gills in the gill-chamber.
21. Try an experiment with a pipette full of carmine poured on the upturned ventral surface of the cephalothorax, the crayfish being lowered into the water, to determine what you can concerning the direction and course of the air-laden water through the gill-chamber.
22. What is the reason for the water being drawn through the gill-chamber?
23. Draw an outline of the cephalothorax, and indicate with arrows the probable direction of the water in passing into, through, and out of the gill-chamber.
24. What is to be learned from comparing the results of pouring first pure water and then some beef broth on the mouth-parts of the crayfish?

25. Plan and describe an experiment for determining whether the crayfish prefers light or dark places.

Make a drawing, dorsal or lateral view (× 1). Label all parts shown.

THE MORPHOLOGY

1. Describe the texture of the skin, noting where it is hard and where it is soft.

NOTE. The body of the crayfish is made up of two distinct regions, the *cephalothorax* and the *abdomen*.

2. Mention two important differences between the cephalothorax and the abdomen.
3. How many *somites* are there in the abdomen?

How many somites do you find there with appendages?
4. Examine the third pair of appendages on the abdomen, and describe its plan or arrangement of parts. (Distinguish *protopodite*, stem; *exopodite*, outer branch; *endopodite*, inner branch.)

What other abdominal appendages are very much like the third pair?
5. Study the complicated "tail," and state to what extent you can find parts which correspond in position (that is, are homologous) to parts in the third abdominal appendages.
6. Describe homologous parts in the first pair of head-appendages (*antennules*).
7. Describe the second pair of head-appendages (*antennæ* and *squames*).
8. Find and describe other appendages which have parts that are homologous.
9. What striking exceptions to the rule of homologous parts do you find elsewhere in the crayfish?

Describe the exceptions.
10. How many pairs of appendages has the crayfish altogether?

How many pairs have structures homologous with that of the third pair of abdominal appendages?

11. Describe the attachment of the *eyes.*

How are the eyes placed with reference to other near-by organs which protect them?

NOTE. The specimens which are relatively broader are the females.

12. What other differences are there between males and females?
13. Examine partially dissected specimens, and give an account of the number, position, structure, and arrangement of the gills.

Make a drawing, dorsal or lateral view (× 1). Label all parts shown.

THE ACTIVITIES

NOTE. The crayfish appears to walk more easily in the water than it does outside.

1. Why is this?
2. Let the crayfish walk the length of the pan about ten times and determine to what extent the legs step forward regularly.
3. Describe the movements of the *pleopods* (swimmerets) in the water.
4. What is the use of the tail-fin (the *uropods* and the *telson*)?
5. How does the animal right itself after being turned on its back in the water?
6. After the crayfish has been left in the air a few minutes, where can you discover bubbles of air escaping, when the animal has been replaced in the water back down and held there?
7. When a solution of carmine has been poured on the ventral surface, and the crayfish then held back down in the water, what happens in the places where the bubbles of air come out?

8. Why is the crayfish not ejecting bubbles of air constantly while in the water?
9. Show by a diagram and arrows the course of the air-laden water passing through the gill-chamber. Tell what the diagram shows.
10. What evidence have you from observation that the antennæ are useful organs?
11. What does the crayfish do when drops of beef broth are poured on its mouth-parts?
    What sense is this experiment a test for?
12. To what extent are the eyes and the eye-stalks movable? What are the probable advantages of having the eyes movable?
13. Plan an experiment to determine whether the crayfish prefers light or dark places.

INTERNAL ANATOMY OF THE CRAYFISH

The student will find that he can dissect a freshly killed specimen of the crayfish more easily than a preserved specimen.

The *gill-chamber* and the *gills* may be exposed by cutting off one side of the *carapace* with scissors. By immersing the specimen in water, the detail of structure of the gills can be ascertained. The attachment of the gills to the body-wall and to appendages can be seen by manipulating the gills and the appendages. How are the gills adapted in structure to the exchange of gases?

Remove the dorsal portion of the carapace and open the body-cavity. Observe the position and form of the *heart* and the *arteries* branching from it anteriorly and posteriorly. What openings can you find in the heart after removing the thin-walled inclosing sac, the *pericardium?*

On the right and left of the heart lie two slender muscles. Trace them forward and backward to their points of attachment. What work do you think they perform when they contract?

Remove the heart, and ascertain the form and extent of the large organ next below, the *reproductive gland.* If the animal is a female, eggs are usually large enough to be distinguished. Follow the pair of slender tubes from the reproductive gland to their outlet on the surface of the body. Compare your specimen with one of the other sex to ascertain what differences there are in the reproductive glands and the tubes leading from them. Remove the gland.

Cut off the anterior portion of the carapace to a point near the rostrum or beak. Notice the attachment of muscles extending from the dorsal surface of the first large organ encountered here, the *stomach.* Follow this portion of the *alimentary canal* backward to the *intestine,* and the intestine further to its end.

To the right and left of the stomach and intestine is the pair of *digestive glands.* Note their connection, their color and texture.

Lift up the stomach and note the short *gullet* leading to the mouth. Remove the stomach and open it along the ventral surface. Manipulate the "gastric mill," and state how the apparatus can perform its work.

The elaborate *muscular system* of the crayfish is now exposed, and the heavy sheet of muscle extending along the ventral portion of the body-cavity can be traced into the abdomen, and the function of that part safely inferred. If possible, follow out the twisted muscles in the abdomen itself.

The *green-glands,* the excretory organs, lie beneath and in front of the stomach. Trace their connection with the near-by openings on the external surface.

Remove the thoracic and abdominal muscles carefully. Near the junction of the cephalothorax and the abdomen the ventral *nerve-cord,* white in color, may first be seen. Continue to cut away the overlying muscle and follow the nerve-cord to the telson. Note the *ganglia,*—the thickened places in the cord,—how often they occur, and what their relation is to branching *nerves.*

Begin at the posterior end of the cephalothorax and dissect away the hard, skeletal processes extending from below, following the ventral nerve-cord forward and observing and noting all modifications of form as you near the gullet. What is the relative position of the nerve-cord and the gullet? Trace forward to the "brain." What connection has this organ with the eyes and the antennæ?

What evidence of bilateral symmetry do you observe in the internal anatomy of the crayfish?

The crayfish is typical of *invertebrate* animals (without a back-bone) with regard to the relative position of three important systems of organs, — the skeleton, the alimentary canal, and the nervous system. What are the main facts to be noted in the relative position of the systems?

Make drawings of the organs in place as they are exposed, representing in sketch form in each drawing the outline of the body.

Additional Topics for Study

A comparison of the external structure and the activities of the crayfish and the locust.

In regions where crayfishes live, a study of the conditions in their surroundings may be made profitable field-work. Examine meadows for the chimney-making species, and shallow brooks for other species.

What kinds of Crustacea have you seen in the market, and what is the economic importance of each species?

What methods are being employed to prevent the extermination of the lobster, and to replenish the supply?

The following references will be found useful in the study of Crustacea:

R. Rathburn, '87, The Crab, Lobster, Crayfish, Rock Lobster, Shrimp, and Prawn Fisheries, *History and Methods of Fisheries*.

W. P. Hay, '93, Observations on Blind Crayfishes, *Proceedings United States National Museum*, Vol. XVI, pp. 283–286.

F. H. Herrick, '95, The American Lobster, *Bulletin United States Fish Commission* for 1895, pp. 1–252.

H. C. Bumpus, '01, On the Movements of Certain Lobsters, *Bulletin United States Fish Commission*, Vol. XIX, pp. 225–330.

J. A. Harris, '01, Notes on the Habits of Cambarus immunis, *American Naturalist*, Vol. XXXV, pp. 187–191.

W. J. Kent, '01, The Colors of the Crayfish, *American Naturalist*, Vol. XXXV, pp. 933–936.

R. M. Yerkes, '01, Study of Variation in the Fiddler-Crab, *Proceedings of American Academy*, Vol. XXXVI, pp. 417–442.

G. W. Field, '02, The Biological Basis of Legislation Governing the Lobster Industry, *Science*, Vol. XV, pp. 612–616.

A. D. Mead, '03, Habits and Growth of Young Lobsters and Experiments in Lobster Culture, *Publication of Brown University*, Providence, Rhode Island.

A. D. Mead, '04, Experiments in Lobster Culture, *Rhode Island Commission of Inland Fisheries, Thirty-fourth Annual Report.*

E. W. Barnes, '06, Methods of Protecting and Propagating the Lobster, with Outline of its Natural History, *Rhode Island Commission of Inland Fisheries, Thirty-sixth Annual Report.*

V. E. Emmel, '06, The Relation of Regeneration to the Molting Process in the Lobster, *Rhode Island Commission of Inland Fisheries, Thirty-sixth Annual Report.*

F. H. Herrick, '06, Effective Protection for the Lobster Fisheries, *Science*, Vol. XXIII, pp. 650–655.

CHAPTERS XIV AND XV. MOLLUSKS

Suggestions to Teachers

The hard-shell clam or the soft-shell clam can be obtained practically all the year round in coast cities, and oysters except in the summer season. Fresh-water mussels are easily collected in the warm seasons, and may be drawn up in winter-time with rakes extended through holes in the ice. This method is employed by the collectors for pearl-button factories.

In order to open the valve, plunge the animals into boiling hot water and draw them out as soon as the valves part. Cut away one valve by passing a knife close against the inner surface.

Four per cent formalin is the best preservative and hardening fluid. A number of shells should be kept entire to illustrate the relation of valve to valve when spread, and also the position of the adductor muscles. Fresh-water mussels can be kept alive in aquaria.

The European edible snails are brought to American cities for sale in the winter season. Native pond-snails may be kept continuously in aquaria, or collected from ponds in the warm seasons.

Squids cannot usually be obtained except from dealers in zoölogical specimens. It is practically impossible to keep them alive in aquaria except under the most favorable circumstances.

THE HARD-SHELL CLAM

1. Into how many pieces or *valves* is the shell of the clam divided?

   NOTE. Animals that appear to be the same on one side of the body as on the other are said to be *bilaterally symmetrical*, as in man, for example. The "hinge" of the clam-shell is on the dorsal surface.

2. What evidence of bilateral symmetry do you find in the exterior of the clam?

   NOTE. On each side of the hinge is a raised portion of the valve, called the "beak." The beak is nearer to the anterior end than to the posterior end.

3. Draw a diagram about one inch long of either the right or the left valve, and label with the technical terms of location.

   NOTE. The curved concentric lines on the surface of the shell mark periods of growth.

4. Give reasons for all conclusions stated under *a*, *b*, and *c*:
   - *a*. Where must the growth of the shell have begun?
   - *b*. Was the rate of growth uniform?
   - *c*. What part of the shell was most recently constructed?

5. After observing the animal with one valve removed, describe the soft material fitting closely against the remaining valve.
6. Follow the edge of the organ just observed, — the *mantle*, — and find and describe the *siphon*.

   Observe the siphon of a live clam or mussel in an aquarium, and experiment to discover the currents of water.

   NOTE. The *gills* are thin, ribbed organs, lying between the mantle and the body proper.
7. How many gills are there?

   By which edge are the gills attached? (Use technical terms of location.)

   NOTE. The air-laden water must pass over the gills.
8. How does the water probably get into the gill-region?

   DIRECTION. Look for the mouth near the anterior end of the body proper.
9. Describe the opening of the mouth and the form of the delicate tentacles surrounding it.

   How many tentacles are there?
10. What is the probable course the food takes in passing to the mouth?

    (The food consists of minute organisms floating in the water.)

    NOTE. The thick, hatchet-shaped part on the ventral surface of the body proper is called the "foot."
11. In what direction would the foot probably be extended in locomotion during life? (Give reasons for your statement.)
12. What is the number and situation of the muscles that hold the valves together during life?

    What facts collectively indicate the bilateral symmetry of the animal as far as you have observed it?
13. In what ways is this species adapted to a life in the bottom of bays near the shore?

    Drawing. Organs in place (one valve removed) (× 1).

THE OYSTER

1. What evidence do you find in the exterior of the oyster that bears on its symmetry?

   NOTE. The deepest grooves on the shell mark the end of a year's growth.

2. How old was the animal in your shell?
3. Examine a number of valves, and ascertain the differences between those valves which are fastened to other objects in life and the valves which are not fastened.
4. When one valve (the right) has been removed, ascertain how the animal is held within the shell in life.
5. Notice the position of the thin membrane fitting against the valve, and suggest one of its uses from evidence observed at the edge.
6. After observing the margin of the double *mantle* all around, state where, in your opinion, the food-laden and the air-laden water might enter between the valves in life.

   NOTE. The thin, ribbed organs lying next the mantle are the *gills*.

7. How many gills are there, and where are they attached to the body?
8. Find the tentacles and observe the mouth near them. From which direction might food come on its way to the mouth?
9. What new evidence have you discovered since you considered Question 1, bearing on the subject of the symmetry of the oyster?
10. Considering all the points you have discussed and others which may occur to you now, state clearly how the oyster is adapted in structure and arrangement of organs to life at the bottom of bays.

THE GARDEN-SNAIL

1. State whether or not the garden-snail appears to be bilaterally symmetrical. Give evidence.

2. Where is the oldest and where is the newest part of the shell?
3. As you look down upon the *apex* (point) of the shell, in what direction does the spiral turn?
4. What appears to be the function of the shell?
5. Find the eyes, and tell what you discover about their size, form, and peculiar way of disappearing and coming into view again.
6. What is the position of the *tentacles* with reference to the eye-stalks?
7. Examine near the edge of the shell for the single large opening to the lung; tell where it is exactly, and describe what you see of its manner of working.
8. What do you see happening as you look beneath the glass plate on which you have the snail moving?
9. Where do you think most of the slime comes from that the animal gives off?
10. Place a bit of cabbage-leaf near the snail's head. After it has been eating awhile withdraw the leaf and observe the action of the rasping tongue.

Summary Outline of the Mollusca

I. General characters (name the six most important):

a. *d.*
b. *e.*
c. *f.*

II. The classes (arrange as a table):

	1. *Pelecypods.*	2. *Gasteropods.*	3. *Cephalopods.*
Breathing			
Skeleton			
Head			
Sense-organs			
Locomotion			
Examples			

III. Foods, habits, and habitat (discuss for the whole group).

IV. Economic importance (give five cases to show how members of this subkingdom are of economic interest):

1.
2.
3.
4.
5.

Additional Topics for Study

The structure of fresh-water mussels studied after the method suggested in the questions on the clam and the oyster.

The economic value of bivalves as human food.

The pearl-button industry.

The habits of the pond-snail.

The comparison of snails and slugs.

The economic importance of gasteropods.

The structure of squids, cuttlefishes, or devil-fishes.

The geological history of nautiloids.

The economic importance of cephalopods.

For further study of Mollusca, consult the following references:

E. Ingersoll, '86, The Scallop and its Fishery, *American Naturalist*, Vol. XX, pp. 1001–1006.

W. C. McIntosn, '96, Notes on Injuries to Oysters by Boring Forms, *Annals of Natural History*, Vol. XVIII, p. 61.

B. B. Griffin, '97, The Adaptation of the Shell in General, *Transactions of the New York Academy of Sciences*, Vol. XVI, p. 77.

C. F. Simpson, '99, The Pearly Fresh-Water Mussels of the United States: Habits, Enemies, Diseases, *Bulletin United States Fish Commission*, Vol. XVIII, pp. 279–288.

H. M. Smith, '99, The Mussel Fishery and the Pearl-Button Industry, *Bulletin United States Fish Commission*, Vol. XVIII, pp. 289–314.

J. L. Kellogg, '00, The Ciliary Mechanism in the Branchial Chambers of Lamellibranchs, *Science*, Vol. II, pp. 172–173.

F. C. Baker, '01, The Molluscan Fauna of the Genesee River, *American Naturalist*, Vol. XXXV, pp. 659–664.

B. Dean, '01, Notes on Living Nautilus, *American Naturalist*, Vol. XXXV, pp. 819–837.

J. L. Kellogg, '01, The Life-History of the Common Clam, *Bulletin United States Fish Commission*, Vol. XIX, p. 193.

CHAPTERS XVI AND XVII. WORMS

Suggestions to Teachers

Specimens of living earthworms may be obtained in rich leaf-mold, or under flat stones in pastures or wood-lots. Practically all the external structures can be made out in the living animal. The specimens may be kept for a limited period in a box of soil and, when needed, placed singly on a piece of wet paper covering the bottom of a tin pan.

For preparing specimens in a rigid condition, it is best to immerse a supply of living specimens in a tray of water, and then add crystals of potassium bichromate very gradually at brief intervals for a period of two or three hours until the animals are stupefied. They may then be straightened out and immersed in a very strong solution of the mixture for twenty-four hours. After washing out the potassium bichromate, preserve in 70 per cent alcohol.

In coast cities the sandworm is an interesting type for study. Specimens may often be found in the sand and mud at low tide. The services of clam-diggers may best be enlisted if the teacher cannot give the time to such collection. Specimens may be preserved in the same way as already described for the earthworm.

The experiments on digestion and osmosis given here are designed to be carried out by the pupils if the laboratory facilities permit. If the teacher prefers to demonstrate the experiments, certainly he should not do the thinking for the pupils.

THE EARTHWORM

1. What is the shape of the earthworm's body?
   Approximately how many somites are there in the body?
2. What are the differences in color and form between the dorsal and ventral surfaces?
   What differences in form of body and size of somites are there between the anterior and the posterior ends?
   How can you tell which is the anterior end in the living earthworm?

   NOTE. Sometimes a thick band or girdle, called the *clitellum*, is visible near one end of the animal. Its function is to secrete a glutinous case for the eggs.
3. Near which end is the clitellum, and how many somites is it from that end?
   How many somites does the clitellum cover?
4. Can you discover eyes?
5. Describe the appearance and arrangement of the external organs that aid in locomotion.

   NOTE. The earthworm's two sets of muscles also aid in locomotion when they contract. These sets of muscles are made up of fibers. In one set the fibers run longitudinally; in the other they encircle the body.
6. What part of the act of locomotion does each set of muscle-fibers perform?
7. In which direction does the blood flow in the dorsal blood-vessel?
   Study and describe the manner of the blood-flow after comparison with that in your temporal artery.
8. What notice does the earthworm take of being struck lightly on different parts of the body?
9. Have you noticed whether the earthworm appears to choose between light and dark places?
   Drawing, ventral view of the first thirty-five somites (× 2). Label all parts shown.

THE SANDWORM

1. How many regions of the body can you distinguish, and what are they?
2. Where do new somites grow? Give the evidence for your statement.
3. Describe the different kinds of "feelers" on the head, and state the number of each.
4. Describe, locate, and give the number of the eyes.

   NOTE. During locomotion the body shows "concave" and "convex" places at the sides.
5. Observe a concavity change position, and tell whether it moves toward the head or toward the tail.
6. What is the direction of the movement of appendages in a concavity?

   What is the direction of the movement of appendages in a convexity?
7. Explain fully the mechanical advantages gained by having the "stroking" and "recovering" occur as they do.
8. In what direction does the blood flow in the dorsal blood-vessel?

   Compare the rate of flow in the dorsal blood-vessel with that of your own blood in an artery.
9. What organs has this animal about the mouth for capturing prey?

   Drawing, general view of head and five somites (× 3).

ADDITIONAL TOPICS FOR STUDY

A comparison of the structure of the earthworm and the crayfish.

The economic importance of earthworms.

Original study on the adaptation of earthworms to their environment.

The history of the use of leeches in medicine.

The protection afforded by governments against parasitic worms found in meat.

Read *The Formation of Vegetable Mold through the Action of Worms*, by Charles Darwin.

EXPERIMENTS ON DIGESTION

Problem. To determine the effect of various chemicals (organic and inorganic) upon chemical compounds used for food by man and other animals.

Materials and operations. Under ordinary circumstances it would be impossible to obtain digestive fluids from the earthworm. It is necessary, therefore, to take analogous fluids from higher animals in order to test the effect of the various *enzymes* (organic ferments) on food-compounds that are very similar to those used by the earthworm.

Saliva obtained from the human mouth contains an enzyme, *ptyalin*, analogous to *diastase* found in the earthworm. Saliva may be obtained with ease and kept in a test-tube ready for experimenting.

Pepsin is an enzyme which is found in the gastric fluid of the stomach of the higher animals. It may be obtained prepared from commercial chemists, but it is often adulterated in such a way as to be useless for experimenting. It may be prepared by chopping up first the lining of a pig's stomach near the gullet end. Place the bits in a bottle, and pour on five ounces of glycerin to dissolve out the pepsin. After three or four days filter off the solution and keep in a bottle. Make up a 0.2 per cent solution of hydrochloric acid (HCl). In experiments where a combination of pepsin solution and HCl is required, mix one part of HCl to ten parts of the pepsin.

The enzymes, *amylopsin*, *trypsin*, and *steapsin*, are found in the pancreatic fluid secreted by the pancreas of higher animals. The pancreatic fluid is thought to have an action on foods analogous to that of intestinal secretions of the earthworm and

other invertebrates. Pancreatin, a preparation made by commercial chemists, is easy to use, but it is sometimes adulterated.

Soak the pancreas of a pig or sheep in water twenty-four hours. Then cut it into small pieces, and dissolve out the enzymes in ten times the volume of glycerin. After three or four days filter off the liquid. Make up a 1.5 per cent solution of sodium bicarbonate (an alkali), which may be combined with the glycerin solution in the ratio of ten to one.

The following food-compounds may be selected for experimentation: starch, grape-sugar from raisins, white of egg (proteid), and fat.

A supply of clean test-tubes set in racks should be numbered and a list made of the contents to be placed in them. In making up a list of chemical combinations to be tested, the student should keep in mind the nature of the problem as stated at the beginning. The problem is to ascertain facts hitherto unknown to the student, not to verify statements made in a book.

The following list contains the most essential combinations:

1. Starch and water.
2. Starch and saliva.
3. Starch and pepsin.
4. Starch and pancreatic fluid.
5. Grape-sugar and water.
6. Grape-sugar and saliva.
7. Egg and water.
8. Egg and saliva.
9. Egg and pepsin.
10. Egg and pancreatic fluid.
11. Fat and water.
12. Fat and saliva.
13. Fat and pepsin.
14. Fat and pancreatic fluid.

Supplementary list for more extended experimentation:

1. Starch and pepsin and HCl.
2. Starch and pancreatic fluid and HCl.
3. Starch and pancreatic fluid and alkali.
4. Egg and pepsin and HCl.
5. Egg and pepsin and alkali.
6. Egg and HCl.
7. Egg and alkali.
8. Egg and pancreatic fluid and HCl.
9. Egg and pancreatic fluid and alkali.
10. Fat and pepsin and HCl.
11. Fat and pancreatic fluid and HCl.
12. Fat and pancreatic fluid and alkali.
13. Fat and HCl.
14. Fat and alkali.

Tests. (1) For starch, iodine.
(2) For grape-sugar, Fehling's solution.
(3) For proteids, the biuret test.
(4) For peptones, the biuret test.
(5) For fats and oils, miscibility with water and chloroform.
(6) For acids and alkalis, litmus paper.

Fehling's solution: Prepare by dissolving white and green Fehling's tablets in two inches of water in test-tube over flame; add one-half inch sodium hydroxide or potassium hydroxide, and fill tube with water. This is enough for five tests.

The biuret test: Boil the unknown substance with some sodium hydroxide or potassium hydroxide; then add drop of copper sulphate.

A violet color indicates the presence of proteid or other albuminous substance.

By comparing the action of iodine on the various food-compounds the starch test may be ascertained. By comparing the action of Fehling's solution when mixed with the compounds the sugar test may be learned.

Results. State in detailed form the results obtained on testing the food-compounds before they have been treated with the digestive enzymes, and afterward.

Conclusions. State the kinds of food that would be acted upon in digestion, and what the result in each case would be.

ABSORPTION

(Principle of osmosis)

Problem. To determine the extent to which various food-materials will pass through the wall of an intestine.

Materials and operations. Obtain sections of sheep's or pig's intestine four or five inches long from a sausage-factory. These may be kept in glycerin or formalin until needed. To prepare for the experiments, collect a few milk-bottles or marmalade-jars, clean them, and cut the same number of sections of one-fourth

inch glass tubing about nine or ten inches long. Heat one end of each piece of tubing to a viscid condition, and turn that end on a pencil of charcoal to increase the diameter slightly. When you are ready to begin the experiments, smear the enlarged end of a glass tube with a little vaseline, slip it into one of the pieces of intestine, and bind the two firmly with many turns of heavy linen thread. Close the opposite end of the intestine also with linen thread. Fill the sac thus made and part of the tube with water, to see that you have an apparatus without leaks.

Now fill one sac with a saturated solution of common salt (No. 1), another with grape-sugar obtained from raisins chopped in a little water (No. 2), a third with boiled starch (No. 3), a fourth with raw white of egg and water (No. 4), and a fifth with peptonized white of egg (No. 5). Pour tap water into the bottles until about two thirds or three fourths full, and into each lower a sac with tube until the water in the bottle is level with the fluid in the tube. Clamp in place with two pencils and rubber bands adjusted across the mouth of the bottle. If the student performs this experiment himself, he should tell what he did in setting up the experiments.

Results. After one or two hours observe and state whether there has been any change of level in the surface of the water in each bottle, and what change, if any, has occurred in the height of the fluid in the tubes.

Draw off a pipette full of the water in bottle No. 1 and pour it into a clean test-tube. Test this with a little silver nitrate, and note the result. Try some tap water and then some salt with the same test. Explain whatever difference in result you obtain.

Draw off some water from bottle No. 2, pour it into a test-tube, treat with Fehling's solution, and heat. Test tap water and then some grape-sugar in the same way, and explain whatever difference in result you obtain.

Draw off some water from bottle No. 3 and test with iodine. Try some tap water and then some lump starch with the same test, and account for the difference in results.

Draw off some water from bottle No. 4 and make the biuret test. Try also some tap water and then some white of egg; make the biuret test, and compare and account for the results.

Test water from bottle No. 5 in the same way you made the test for No. 4. After making tests for comparison, account for the results. Write an account of what was done under Results.

Conclusions. (1) What have we demonstrated with regard to a property possessed by those food-materials which may be formed by the action of digestive enzymes on other food-materials? Why is digestion of some foods necessary?

(2) When two fluids separated by a membrane pass through and mingle with the fluid on the opposite side, we have illustrated a condition called *osmosis*. Speaking of fluids as dense or less dense, in which direction is the flow greater?

(3) The solids in solution which diffuse (flow) through a membrane with ease are called *crystalloids;* the others are called *colloids*. Blood is a colloid. How are crystalloids and colloids situated in the actual process of absorption in animals?

CHAPTER XVIII. ECHINODERMS

Suggestions to Teachers

The class study of starfishes and other echinoderms is practically limited to the examination of prepared specimens, unless the school is near the seashore. In places where the coast is rocky, starfishes and sea-urchins are easily obtained in the tide-pools; and, in fact, the study of these forms could be pursued in no better place than by the tide-pool until the investigation reaches a point where laboratory appliances are needed, as in dissection.

If it is possible to have running sea water in the laboratory, many interesting observations can be carried on, but standing sea water, as in balanced aquaria, does not offer conditions favorable to these animals.

Hydra is so common in bodies of quiet fresh water that every school can supply itself by collecting small fresh-water plants and sticks, and stocking an aquarium with them and water from the same situation. The pond water is necessary in order to insure an abundant supply of food for the hydras. This food consists of small Crustacea, such as Cyclops and Daphnia.

Sea-anemones can be kept alive in balanced sea-water aquaria. They will live on small bits of animal food, which may be passed to their oral region on the point of a stick. Care should be taken to clear out from the aquarium all particles of food which the animals do not swallow.

Medusæ and hydroids cannot be studied alive with profit except in marine laboratories.

THE STARFISH

NOTE. The central portion of the starfish is called the disk and the "arms" are called the rays.

1. Compare the diameter of the disk with the width of a ray and also with the length of a ray.

   How many rays has your specimen?

   NOTE. We apply to the upper and lower surface of the starfish the adjectives "aboral" and "oral" respectively.

2. Which surface is the more convex?

   What are the differences in general shape, size, and arrangement between the spines on the aboral and most of those on the oral surface?

   NOTE. The mushroom-like plate on the aboral surface is called the "sieve-plate." Through it water passes in and out.

3. Where is the sieve-plate with reference to the disk and to near-by rays?

   NOTE. The mouth is on the oral surface of the disk.

4. Examine to get an idea of the mouth, and describe it.

NOTE. The grooves on the oral surface of the rays are called the *tube-foot grooves*. In them may be seen the dried *tube-feet*.

5. How many long rows of these tube-feet can you make out? Show by a diagram how twenty adjacent tube-feet are arranged in the groove.

Drawing, oral view (× 1).

ADDITIONAL TOPICS FOR STUDY

The prevalence of crinoids in geologic times.

The variety of forms in sea-urchins.

The habitat and habits of sea-slugs.

For further information, consult the following:

A. and E. C. Agassiz, *Seaside Studies in Natural History.*

A. Hyatt, '72, *Common Hydroids, Corals, and Echinoderms.*

J. H. Emerton, '78, *Life on the Seashore.*

G. J. Romanes, '85, *Jellyfish, Starfish, and Sea-Urchins.*

A. Heilprin, '88, *Animal Life of Our Seashore.*

A. D. Mead, '00, The Natural History of the Starfish, *Bulletin United States Fish Commission for 1899*, pp. 203–224.

CHAPTER XIX. CŒLENTERATES

THE HYDRA

1. What is the color of the hydra?
2. Make note of whatever varieties of shape and size you find, and account for any differences you see.
3. What external organs are noticeable?
4. By what portion of the body does the hydra maintain its hold on other objects?
5. Cause the hydra to loosen its hold by pushing it gently with the smooth end of a glass rod, and report on what it does both at the moment and until it comes to rest again.
6. Since the hydra has no connected nervous system, what substance of the body probably manifests the sensitiveness you have observed?

7. Place in the glass vessel with the hydra a live water-flea (Cyclops), and observe what happens when the crustacean comes near the hydra.
8. By examining several hydras it is possible to find buds and learn the process of non-sexual reproduction.

A MEDUSA (GONIONEMUS)

1. What is the nature of the substance of a medusa?
2. What is the form of the body?
3. What are the dimensions of your specimen?

   NOTE. The large, dark, internal bands contain the *eggs* or the *spermatozoa*. The bands are called *gonads*.

4. State the number and describe the arrangement of the gonads.

   NOTE. The slender hanging organs are the *tentacles*.

5. Where are the tentacles, and how many are there?

   NOTE. The thin sheet of tissue partially covering the flat side is called the *velum*.

6. How wide is the opening in the velum?
7. Since the medusa swims by contracting a circular muscle at the rim, what part of the body must go forward?

   Give the reason for your answer to Question 7.

ADDITIONAL TOPICS FOR STUDY

The habits of sea-anemones.

The colony of a Portuguese man-of-war.

The source and method of formation of red coral and its manufacture into ornaments.

Theories of the formation of coral reefs and islands.

For further study of the group, the following references will be found useful:

C. Darwin, *The Structure and Distribution of Coral Reefs.*

J. D. Dana, '72, *Corals and Coral Islands.*

A. Hyatt, '72, *Common Hydroids, Corals, and Echinoderms.*

A. and E. C. Agassiz, *Sea-Side Studies in Natural History.*

E. R. Downing, '02, Ingestion and Digestion in Hydra, *Science*, Vol. XV, p. 523.

M. Hefferan, '02, Experiments in Grafting in Hydra, *Science*, Vol. XV, p. 467.

CHAPTER XX. SPONGES

Suggestions to Teachers

According to a leading authority on fresh-water sponges, the gemmules may be germinated and observed on the microscope-slide. By the aid of carmine granules, the current of water leaving the osculum may be observed. The authors have not tried this way of studying sponges, but it offers the only chance of learning about the activities of a living sponge. In the fresh-water sponge gemmules resemble small seeds; they can be collected in August or September and kept in a dried condition until required for observation.

Although the various species of fresh-water sponges are widely distributed over the country, it requires not a little search along the margins of ponds to find them. The masses are flat and are generally from about one to a few inches across but occasionally much larger. They vary in color from gray to green; they occur on submerged stones, sticks, and dead leaves.

The skeletons of marine sponges offer a good opportunity to trace out the systems of canals. The variety of bath-sponge known as "hard heads" may be obtained cheaply at drug stores. If these are cut to show the relation of the oscula to the canals, the pupil can then trace the system. The zoölogist is more likely to find interesting specimens among a new barrel of sponges at the druggist's than is apt to be the case among those found in show-windows.

THE BATH-SPONGE

1. Cut the bath-sponge through the *osculum* down to the large open space called the *cloaca.* From there trace outward into the sponge until you discover the limits of that particular system of canals. How many such systems are there in the entire sponge-mass?
2. What, if any, connection have the canals that you have traced from the cloaca with the smaller openings on the surface of the sponge?
3. What evidence can you discover to support the common belief that sponges live fastened to the bottom of the ocean?
4. Tear off a bit of the skeleton and compare it with a bit of the common sulphur-sponge.
5. What can you say now concerning the reason for the greater commercial value of the bath-sponge?
6. Examine some of the fibers of the bath-sponge with the compound microscope, and compare them with the pieces of the skeleton of a fresh-water sponge.

Additional Topics for Study

The collection and preparation of sponges for the market.

Consult Fresh-Water Sponges, *Publication of Philadelphia Academy of Sciences,* by E. Potts; and Commercial and Other Sponges, by A. Hyatt.

CHAPTER XXI. PROTOZOANS

Suggestions to Teachers

Amœba and Paramœcium, as well as many other species of single-cell animals, may be obtained in large quantities in a variety of ways. The favorite way of getting Amœbæ is to collect some slime and sticks from a small stagnant pool, and allow this to

stand in a jar a week or two. It is possible, however, to start a culture from dead leaves covered with ordinary tap water, or from decaying water-plants, and even from decaying vegetables, such as potatoes, in water.

To obtain Paramœcia, the simplest way is to put a handful of dried hay in a battery-jar and cover with pond water or tap water. The hay rots in the presence of countless bacteria. The bacteria constitute the food-supply of the Paramœcia, which appear in two or three weeks, either from a few individuals which came with the water or from encysted individuals attached to the hay.

The authors have found that a stock of Paramœcia once obtained need never be destroyed by the ravages of other organisms if the water in the jar is allowed to evaporate and is replenished the next year. Undoubtedly the evaporation of the water causes the Paramœcia to become encysted and prevents certain other organisms (such as rotifers) from making their appearance.

THE AMŒBA

1. Place a drop of the amœba culture on the slide, cover with the cover-glass, and search till you find an amœba. Why do you have difficulty in finding a specimen?
2. Observe the animal as it moves, and find out whether the direction of movement is at all definite.
3. Make a series of ten successive sketches, showing as accurately as you can the outline of the animal. On comparing your sketches and the appearance of the amœba, what generalization can you make with regard to the form of the animal?
4. What happens when you give the glass slide a very light tap? As indicated by the result, what property of protoplasm is possessed by the amœba? What sense has been manifested by the animal?

5. When the amœba begins to move again, note the difference between the outer layer of protoplasm and the inner portion.
6. Which begins the act of motion, the *ectoplasm* (outer layer) or the *endoplasm* (inner substance)?
7. When the amœba comes in contact with an obstruction what happens?
8. Have a supply of microscopic plants ready (diatoms or desmids); draw some of them under the cover-glass with filter-paper, and observe the action of an amœba on coming in contact with one of them.

THE PARAMŒCIUM

1. In what part of the stock culture do the Paramœcia seem to be most abundant? What significance do you attach to the facts as you discover them? (Leave this answer till later, if you like.)
2. Place a drop of Paramœcia on your glass slide, cover with a cover-glass, and notice what they do. (You can see by holding the slide against a dark background.)
3. After ten or fifteen minutes employed in examining the animals under the microscope-objective, remove the slide and notice where the animals have collected. What explanation have you to offer for what you see?
4. After examination with the unaided eye and the low-power objective, describe the manner in which a Paramœcium makes its way across the slide.
5. With all the facilities at your command, what are you able to discover concerning the structure and the manner of working of the locomotor organs?
6. How are the locomotor organs distributed on the body? How do you explain the fact that you can see but a very few of them at one time?

7. If you were asked to make a clay model of a Paramœcium, what details of form of the exterior would you have to take note of?
8. Look again at a slowly moving animal, and observe the changes in position it makes. While it is going forward, in what other direction is the body moving?
9. Do you now see any explanation for the peculiar fact you recorded in Answer No. 4?
10. Under what conditions, as far as you can observe them, does the Paramœcium change its customary direction of movement? What difference is there in the form of the anterior and the posterior ends?
11. Learn what you can of the position and appearance of the *gullet* and the *mouth.*
12. What evidence do you see of food coming into the body?
13. Find a quiet animal and observe the working of the two *contractile vacuoles.*

Additional Topics for Study

The relation of Protozoa to disease in man.

The importance of Protozoa in forming strata of the earth's surface.

The history of the discoveries bearing on yellow fever.

For further information, consult some of the following references:

Hodge and Aikins, Daily Life of a Protozoön, *American Journal of Psychology*, Vol. VI.

H. S. Jennings, '99, The Psychology of a Protozoön, *American Journal of Psychology*, Vol. X, pp. 503–515.

G. N. Calkins, '01, The Protozoa, *Columbia University Biological Series.*

A. W. Peters, '01, Some Methods for Use in the Study of Infusoria, *American Naturalist*, Vol. XXXV, pp. 554–559.

H. S. Jennings, '04, Contributions to the Study of the Behavior of Lower Organisms, published by the Carnegie Institution.

G. N. Calkins, '06, The Protozoön Life-Cycle, *Science*, Vol. XXIII, pp. 367–370.

H. C. Weeks, '06, The Practical Side of Mosquito Extermination, *Science*, Vol. XXIII, p. 379.

CHAPTERS XXIII AND XXIV. FISHES

Suggestions to Teachers

For the study of the living fish, the authors have either utilized the resources of the aquarium in Battery Park, New York, which they visit with their classes, or they have furnished their pupils with goldfish (*Carassius auratus*) in gallon battery-jars or small aquaria, for study during the school period. Suggestions for study by the pupil are here presented for both methods.

Goldfish are easy to procure and keep alive in the school aquarium. Several other species would do as well, or better, in some respects. The colors of goldfish are due to artificial selection; in the ponds and rivers of its original habitat in China the coloration is greenish or olivaceous. Catfish are interesting for comparison. The circulation of the blood in the fins of the fish may be studied by wrapping the fish in a piece of wet cloth and placing it on a support in such a way that a fin may be beneath the objective of a compound microscope.

If there is a public aquarium within reach, much valuable work may be done there by the pupils even unaccompanied by the teacher. Some suggestions for such studies will be found farther on.

For the study of the external structure and the internal anatomy, the yellow perch has been used. It may be obtained in the New York fish-market throughout the year. The cunner (*Tautogolabrus adspersus*) and the porgy (*Stenotomus chrysops*) have also been used and found satisfactory. For work on the nervous system, material hardened in alcohol should be used.

THE LIVING GOLDFISH

Examine the living goldfish. What divisions of the body are apparent? In what way is the shape of the body adapted to the life of the fish in the water? What is the character of the body-covering? Is the fish bilaterally symmetrical? Are the dorsal and ventral lobes (divisions) of the tail symmetrical? Is the goldfish protectively colored?

Try to determine the functions of the fins. Of the two pairs of fins on the lateral surfaces, the anterior are the *pectoral*, the posterior are the *ventral*. The fin on the back is the *dorsal*, the tail-fin is the *caudal*. The median fin on the ventral surface near the caudal fin is the *anal* fin. Which fin is the chief organ of locomotion? Which fins seem to be useful in maintaining equilibrium?

Notice the action of the mouth, and the *opercula* (gill-covers) placed on the sides of the body just behind the head. What is the reason for the constant motion observed?

Are the eyes movable? Are they provided with eyelids? What means of protection have the eyes? How does the field of vision in the goldfish compare with our field of vision?

Scatter a very little fish-food on the surface of an aquarium containing goldfish. Report on the method of taking food. What sense does the goldfish seem to depend on to get its food? Would it be possible to deceive the goldfish with material that was not food? Try it with small pieces of paper similar in color and shape to the bits of fish-food. Is there any evidence that the goldfish can taste?

THE LIVING FISH AT THE AQUARIUM

Choose a fairly large fish that shows some disposition to move about and to open and close the mouth. Note the name of the fish, its geographical distribution, and any other information which the label may afford.

Follow the suggestions for the study of the living goldfish, except those relating to the method of taking food. Include any observations of interest concerning points not mentioned.

EXTERNAL STRUCTURE OF THE YELLOW PERCH

General. Recall your observations on the shape of the body of the living goldfish, and consider whether the perch is equally well adapted in shape to life in the water. In addition to the body-covering of *scales*, note the slimy secretion (mucus) poured out abundantly from glands in the skin. Of what value is this secretion?

The perch inhabits fresh-water streams, ponds, and lakes. Do you consider that the perch is protectively colored above or below? Do you know any animals likely to feed on the perch? Can you suggest any explanation of the brilliant coloration of the pectoral fins?

Remove a scale from the lateral surface and examine with a magnifying-glass. Are the colors due to the presence of the scales? Examine a scale from the "lateral line," which extends along each side from the operculum to the caudal fin. Do the scales along this line differ from those on other parts of the body? Describe briefly.

The head. Study the *jaws*. By means of the forceps open and close the mouth, noting the motion of each jaw. Are teeth present? If so, where? Examine and describe the *tongue*.

By means of a bristle determine whether the *nostrils* open into the mouth. Examine the *eyes*. The dark circular space in the eyeball is the *pupil;* the colored circle surrounding it is the *iris;* the transparent skin covering both is the *cornea*. What is the color of the iris in the perch?

The trunk and its appendages. Study the *fins*. Note the long structures, *fin-rays*, which support the fin. The fin-rays are of two sorts; find them, describe each kind, and tell in

which fins each is located. What is the probable function of the hard rays in addition to supporting the fin-membrane?

Raise the *operculum* on one side, and note the position of the *gills* beneath. Open the mouth widely, at the same time depressing the tongue, and get a general idea of the relation of the gill-chamber to the mouth-cavity.

Make a drawing of the perch, natural size, from one of the lateral aspects, labeling all the parts shown.

INTERNAL ANATOMY OF THE YELLOW PERCH

Hold the fish in the palm of the left hand, with the ventral surface upward and the head pointing away from you. Thrust the point of the scissors through the body-wall just in front of the anal opening, anterior to the anal fin. Cut forward in the median line as far as the ventral fins, being careful not to cut deep enough to injure the organs within. Cut towards the dorsal surface at right angles to the first cut at its beginning, as far as the body-cavity extends, being careful not to cut into the air-bladder, which lies in this portion of the body-cavity. A similar cut should be made from the anterior end of the first cut to the pectoral fins. The flap of skin thus formed between the two transverse cuts may be turned back, or cut away entirely, exposing the organs of the body-cavity. Note the silvery lining membrane, the *peritoneum*. If the perch is dissected in the spawning season, the reproductive organs will be the most prominent when the body-cavity is opened. See statements under The Reproductive System.

The digestive system. In the front part of the body-cavity, and mostly on the left side, is a reddish-brown mass, the *liver;* attached to its posterior surface is a thin-walled sac of a greenish or yellowish color, the *bile-sac*. Of how many lobes does the liver consist? Just posterior to the liver is the *stomach*. Pass a probe backward from the mouth through the *pharynx*

(the chamber into which the gill-slits open) and through the short *œsophagus*, in order to determine the shape and size of the stomach. What peculiarity do you notice in its structure? At the junction of stomach and intestine note several worm-like branches (*pyloric cæca*). How many are there? Do they open into the alimentary canal? Trace the course of the intestine from the stomach to the anal opening, tearing away gently the attachments of the *mesentery* (a portion of the peritoneum which is folded about the organs, serving to keep them in place). In the course of this examination find a small, deep red body, the *spleen*, close to the stomach. Is it connected with the intestine? It will be found advisable to make a loop of the intestine outside the body-cavity, in order to have it out of the way for further dissection.

The reproductive system. In the posterior portion of the body-cavity are the reproductive organs, — a pair of whitish *spermaries* in the male, or a granular, yellowish *ovary* in the female. Both organs vary much in size at different seasons; in the spawning season they will have to be removed before proceeding to the dissection of the digestive organs. Decide whether your specimen is a male or female, and trace the *sperm-ducts* or the *oviduct*, as the case may be, to the surface of the body at the *urinogenital opening*.

The excretory system. In the dorsal region of the body-cavity is a white sac, the *air-bladder*. Is it connected with the alimentary canal? By cutting into the air-bladder, the dark red *kidneys* may be located just dorsal to it, and closely placed along the line of the back-bone. Trace tubes, the *ureters*, leading to a small pink sac, the *urinary bladder*, placed just dorsal to the urinogenital opening.

The circulatory system. Raise the operculum on one side, exposing the *gills*. How many gills has the perch? Remove one of the gills by cutting with the scissors at each end where it is attached. Note the supporting *gill-arch*, with the teeth-like

gill-rakers on one side and the red *gill-filaments* on the other. What is the probable function of the gill-rakers? of the gill-filaments?

Continue anteriorly the first cut made in opening the body of the fish, cutting through the girdle of bone which supports the ventral fins. By carefully cutting away the body-wall as far forward as the opening into the gill-chamber and far enough toward the dorsal surface of the perch to remove the pectoral fin of one side (the same side of the fish already opened), the *pericardial cavity*, just anterior to the general body-cavity, will be exposed to view. The pericardial cavity is separated from the body-cavity by a partition, the *false diaphragm*. It contains the *heart*, a reddish organ with several divisions. The red, angular, posterior portion is the *ventricle;* the darker, irregular mass above and a little in front of the ventricle is the *auricle;* the anterior swelling is the enlarged base of an artery (the *aorta*) and is called the *bulbus aortæ*. Trace the course of the large vein (*hepatic vein*) from the liver through the false diaphragm to the large blood-vessel (*venous sinus*) which extends posteriorly from the auricle. Trace as far back as possible any other veins which you find entering the venous sinus. Trace the course of the aorta and its branches as far as possible towards the gills. After passing through the gills, the fine divisions (*capillaries*) of the artery unite to form the *dorsal aorta*, which passes backward just beneath the back-bone. Trace the course of the arteries from the gills to the dorsal aorta. The dorsal aorta distributes blood to the body generally, whence it returns through veins to the venous sinus, thus completing its circulation.

The muscular system. The *muscles* of the fish are in the form of two thick plates, on opposite sides of the back-bone. Cut into the flesh along the back-bone to get a general idea of the muscles.

The skeletal system. Scrape away enough of the flesh to examine one of the vertebræ, or divisions of the back-bone

(*vertebral column*). Note the central portion of the vertebra and the *spinous processes.* About how many pairs of *ribs* has the perch? An enlargement at the anterior end is the *skull,* consisting of the bones of the brain-box, or *cranium,* and the *jaws,* which are articulated with the cranium.

Make a drawing of the perch, natural size, from one of the lateral aspects, showing the organs studied so far. Label the parts properly.

Make a diagram of the circulatory system (× 2).

The nervous system. Cut and scrape away carefully the muscles on the head so that it will be possible to slice off the upper surface of the cranium and study the *brain.* Notice that the brain is composed of several divisions. Does it fill the entire cavity of the cranium? Cut down to expose the *spinal cord,* which extends backward through the vertebral column. The spinal cord enlarges anteriorly into the *medulla oblongata,* in front of which is the *cerebellum.* Anterior to the cerebellum are the two large *optic lobes,* forming the most pronounced feature of the brain; and the two smaller *cerebral hemispheres* (*cerebrum*), which taper into the *olfactory tracts,* communicating with the nostrils. Identify these divisions and trace also the *optic nerves* to the eyes. With what division of the brain are they connected?

Make a drawing of the brain viewed from above (× 2).

Additional Topics for Study

Give a résumé of the last report of the Bureau of Fisheries.

What fishes are found in the vicinity of your city? Which kinds belong to the salt-water fauna and which to fresh-water?

What do you know of the habits of any fish, from your own observations?

Visit a fish-market to learn the principal kinds of food-fishes to be found there at this season. Examine some of the most important kinds so as to be able to describe them briefly in class. Tell

where they are secured. Quote prices of different kinds; compare with prices of meat. Consult *Farmers' Bulletin No. 85*, United States Department of Agriculture, Fish as Food, by C. F. Langworthy.

Look up the life-history and habits of salmon.

If possible, visit a fish-hatchery, and report on your visit.

Report on different methods of capturing fishes.

Look up the structure and habits of deep-sea fishes. Under what physical conditions must life exist in the depths of the sea?

Look up the life-history of the eel.

Describe the methods of capturing a game-fish, such as the salmon or trout. What game-fish have you ever succeeded in capturing? Describe some experience in your fishing.

Read Izaak Walton's *Complete Angler*. What is your opinion of the book?

Besides being an article of food, what other important products do we obtain from fish?

Look up the fresh-water or salt-water fisheries of your home region.

Visit a museum of natural history. Study especially the great groups into which fishes are divided. Take your *General Zoölogy* with you or look up the classification of fishes before you go. Make a report in composition form of your study.

Study some of the following topics at an aquarium: the various modifications of form of body in different fishes, different methods of locomotion, the colors of fishes, special means of defense, bottom-feeding fishes and their special modifications, special adaptations for obtaining food, the structure and activities of the sea-horse (*Hippocampus*). Read Notes on the Functions of the Fins of Fishes, by A. Duges, in *Science*, Vol. XXII, No. 572, December 15, 1905, p. 799.

For some suggestions concerning the evolution of fishes, consult the two following articles by President David Starr Jordan, of Leland Stanford, Jr., University: The Evolution of Fishes, in the *Popular Science Monthly*, Vol. LX, No. 6, April, 1902; and

The Origin of the Fins of Fishes in the same periodical, Vol. LXI, No. 6, October, 1902.

For the geological development of fishes, consult *Animals before Man in North America*, Chapter IV, by Frederic A. Lucas; *Animals of the Past*, Chapter II, by Frederic A. Lucas; *Extinct Animals*, Chapter VI, by Professor E. Ray Lancaster.

Consult some of the following references for the question of instinct and intelligence of fishes:

N. A. Smith, '97, Have Fish a Memory?, *Natural Science*, Vol. X, p. 118.

Edward L. Thorndike, '99, Psychology of Fishes, *American Naturalist*, Vol. XXXIII, p. 923.

R. W. Schufeldt, '00, Psychology of Fishes, *American Naturalist*, Vol. XXXIV, p. 275.

Norman Triplett, '00, Educability of the Perch, *American Journal of Psychology*, Vol. XII, p. 350.

CHAPTERS XXV AND XXVI. AMPHIBIANS

Suggestions to Teachers

Frogs may be obtained from dealers in laboratory supplies, or captured by means of a stout hand-net along the margins of rivers, ponds, and lakes, and in marshes. They should be kept in a covered box, with a sod, which should be kept moist. The box should be kept in a cool, damp place. Different sizes of specimens should be kept separated, as the smaller ones may be devoured by the larger ones. Frogs may be killed by placing them in a tightly covered receptacle in which a cloth or sponge with a few drops of chloroform has been placed.

The endoskeleton may be studied by means of prepared skeletons, which may be purchased, or prepared by the pupils. The nervous system can best be studied in alcoholic specimens. Injected specimens will be found useful in working out the circulation. The circulation of blood in the frog's foot may be studied under the microscope.

The toad is especially favorable for study, since it passes through its transformations within so short a time. The common red-spotted newt is very generally available, and is easy to keep alive in both the young terrestrial stage and the adult aquatic condition. The pupils should be encouraged to collect and identify the amphibians of their home region, and to study their life-history.

THE LIVING FROG

Examine the living frog. What are the body-divisions? What makes the prominent hump on the dorsal surface? What is the body-covering? Does the skin secrete mucus? Compare with the body-covering of the fish and of man. Consider how the shape of the body is adapted to the frog's environment. Is the frog bilaterally symmetrical?

Considering the environment of the frog and its probable enemies, is it likely that the coloration is protective? What enemies of the frog do you know?

What means of locomotion has the frog? Compare with the fish and with man. How many methods of locomotion has the frog? Try the frog on land and in the water. What divisions do you make out in the front legs? the hind legs? How do they compare with the divisions of the limbs of the human body? Notice especially the way the hind legs are bent when the frog is at rest. What differences do you notice in the structure of the hind and front feet? What difference in function?

Note the movements of the throat, nostrils, and sides of the body. What process is indicated? Describe. How many movements of the throat occur per minute? Is their number affected by the stimulation caused by handling the animal?

Observe the slight pulsations at the right and left of the posterior end of the vertebral column, indicating the position of two *lymph-hearts*, the pulsations of which assist in the movement

of lymph, a colorless fluid, the function of which is supplementary to that of the blood.

Notice the *eyes*. Can they be retracted? How are they protected? Touch gently with the forceps, to observe the third eyelid (*nictitating membrane*), which may be seen to pass across the eyeball. Describe its action and suggest its function. Compare the field of vision in the frog with that of the perch and man. In the eye of the frog do you find parts similar to those already observed in the fish? What is the shape of the pupil?

Just back of the eyes will be found the *tympana*, the external indication of the frog's ears. Have you any evidence that the frog depends much on its sense of hearing?

Notice the size of the frog's *mouth*. Compare with the mouth of the tadpole. If possible, get a frog to feed by suspending an earthworm or a small piece of meat by a thread in front of its head, gently swinging the thread backward and forward. Report on the method of taking food. On what senses does the frog seem to depend for knowledge of the presence of food?

Record the frog's behavior when touched on the snout repeatedly with a pencil or forceps. Is the frog timid? Does the frog react in a similar manner to all the stimulations? Do you consider the frog intelligent?

Are there any other observations of interest which you can add to your account of the living frog?

Make a drawing of the frog, natural size, sitting position, as seen from one side. Label as many parts as possible.

THE LIVING FROG

(*Alternative method with numbered paragraphs*)

1. Describe the coloration of the frog.
2. Give some notion of the texture and "feel" of the skin.
3. What is the attitude of the frog when at rest on a solid?
4. How does the animal move on a solid?
5. How does the frog swim?

6. How does the frog remain at rest on the water?
7. How long may it remain under the water?
8. What means has the animal of protecting its eyes? (Test by touching the skin near the eye.)
9. What kind of movement can you see at the nostrils? What is the meaning of that movement?
10. Describe the breathing of the frog completely.
11. Describe the appearance of the ears.
    What structure in the human ear does the external part of the frog's ear probably correspond to?
12. How many toes has each fore foot?
    Try putting your finger under the fore foot of the frog, to see what the toes may be useful for.
13. How many toes are there on each hind foot?
14. What is the relative length of the first and the last toe on each hind foot?
    Which toe of the hind foot is the longest?
    NOTE. The males may be distinguished from the females by the fact that the male has a much thicker "thumb" than the female.
15. Make comparisons of several specimens, and determine whether yours is a male or female.
    If opportunity permits, observe the way the frog "croaks." Do males and females croak equally loud?
16. Name and describe briefly three adaptations found in the various external organs of the frog. State in what way the organs mentioned are fitted to particular uses.
    Draw general view (× 1) in some natural attitude. Label all parts shown.

INTERNAL ANATOMY OF THE FROG

Put the frog in a dissecting-pan containing water, dorsal surface down and the head pointing away from you. With the forceps lift the skin, and with scissors or scalpel cut through the skin of the ventral surface in a median line from near the

posterior end of the body to the tip of the lower jaw. From the beginning of this incision cut outward on either side. From just behind the front legs make similar transverse incisions, turning back or removing the flaps of skin thus formed.

The muscular system. Note the narrow muscle-bands along the median line of the trunk. This muscle is the *rectus abdominalis.* What effect would its contraction have? Note the broad fan-shaped muscle (*pectoralis major*) passing from the breast-bone to the anterior limb. What is its function? Note the presence of blood-vessels in these muscles and in the flap of skin. Dissect away the skin of the thigh of one hind leg, and, separating slightly some of the larger muscle-masses, make out the position of the muscles which bend and extend the leg as a whole; also the position of the muscles controlling the movements of the toes.

The digestive system. Examine the *mouth.* Are the *jaws* provided with teeth? Raise the *tongue* to determine its point of attachment. Can the tongue be protruded from the mouth? Compare the tongue and jaws of the frog with those of the perch.

Prick a hole in the tympanum with the dissecting-needle, and pass a bristle through the Eustachian tube to the mouth-cavity, noting the spot where the bristle enters.

Determine whether the nostrils communicate with the mouth-cavity.

Lift the body-wall and cut along the median line to the lower jaw, being careful not to injure the organs beneath. It will be necessary to cut through the sternum (breast-bone) when the region of the anterior limbs is reached. Cut right and left transversely at the beginning and toward the end of the median incision, and pin back the flaps, exposing the organs of the body-cavity.

Identify the divisions of the alimentary canal. Use a probe, as in the perch. At the end the alimentary canal suddenly enlarges into the *rectum,* or large intestine, which passes without

change of diameter into the terminal *cloaca*. Identify *liver*, *pancreas*, and *spleen*, and make out the ducts leading from the liver and pancreas to the alimentary canal. How many lobes has the liver? Has the frog a *gall-bladder?* To what is the spleen attached? How does the stomach of the frog differ from that of the perch?

The reproductive system. The *ovaries* of the female (much enlarged in the breeding-season) are dark masses in the posterior portion of the body-cavity, close to the kidneys. The *spermaries* of the male are a pair of much smaller, yellowish bodies in a corresponding position. Determine whether your frog is a male or female. At the anterior end of the reproductive organs are the finger-like *fat-bodies*, which are thought to be useful as storehouses of reserve material.

The excretory system. The elongate *kidneys* will be found close to the back-bone. A large sac just beneath the cloaca is the *urinary bladder*.

The circulatory system. Dissect away enough of the body-wall to examine the heart, just anterior to the liver. The thin skin covering the heart is the *pericardium*. In the frog there are two *auricles*, placed anteriorly; the conical posterior portion of the heart is the *ventricle*. From the ventricle a great artery (the *aorta*) subdivides, sending branches to the head, to the lungs and skin, and to the body generally. Trace these blood-vessels as far as possible. Study the blood-vessels at the auricular end of the heart. Follow the large vein (*portal vein*) from the liver to the heart. If possible, trace the blood-vessel (*pulmonary vein*) from the lungs to the heart.

The respiratory system. In order to study the respiratory system, pass a blowpipe down the *glottis* (the opening from the mouth-cavity to the *trachea*, or windpipe) and inflate the *lungs*. What organs in the perch are analogous to the lungs of the frog?

Make a drawing of the frog, natural size, showing as many as possible of the organs studied. Label the drawing properly.

The nervous system. To study the nervous system, pin the frog on its ventral surface, and make an incision along the median line of the back, from the tip of the snout half-way to the posterior end of the body. Cut away the skin and muscles from the dorsal surface of the head, and for a short distance back. Insert the sharp point of the scissors into the opening in the cranium through which the spinal cord passes, and cut around the outer edge of the roof of the cranium as far as the eyes. Chip off carefully enough of the bone to expose the *brain*, and in a similar manner expose the base of the spinal cord. In the brain identify the *medulla oblongata, cerebellum, optic lobes, cerebrum,* and *olfactory lobes.* The cerebellum is very small in the frog. Between the posterior ends of the cerebral hemispheres find the small, medially placed *pineal body.* Cut off the anterior ends of the olfactory lobes and lift the anterior end of the brain to see the *optic nerves.* Cut these to discover other *cranial nerves.* In order to see the *spinal nerves,* turn the frog over, pin it on its dorsal surface, and carefully cut away all tissues along a portion of the vertebral column.

Make a drawing of the nervous system of the frog from above (× 2), as far as you have worked it out. Label the parts shown.

THE LIVING FROG–TADPOLE

Note the shape of the body, and consider its adaptation to the life of the tadpole. What is the body-covering? What means of locomotion has the tadpole? Are the colors protective? What means of protection has the tadpole? Does the tadpole come to the surface to breathe? Note the size of the mouth. In what ways does the tadpole differ from the adult frog?

ADDITIONAL TOPICS FOR STUDY

Collect and identify the different species of amphibians in your locality. Identify by means of Jordan's *Manual of Vertebrates.*

Study the development of the toad from egg to adult form.

Compare the external structure of the frog and toad. How do the frog and toad differ from each other in their habits?

Compare the external structure and life-history of the newt and frog.

What superstitions have you read or heard regarding toads, frogs, and salamanders? Explain the basis for each superstition, if possible.

For the breeding habits of Amphibians, consult the following references: The Frog as Parent, by Professor E. A. Andrews, in *Popular Science Monthly*, Vol. LIX, No. 1, May, 1901; and Unusual Modes of Breeding and Development in Anura, by L. V. Sampson, in *American Naturalist*, Vol. XXXIV, September, 1900, p. 687.

For the geological development of Amphibians, consult *Animals before Man in North America*, Chapter V, by Frederic A. Lucas; and *Prehistoric Animals*, Chapter VI, by Professor E. Ray Lancaster.

For information on the toad, consult:

C. F. Hodge, *The Common Toad*, Nature Study Leaflet.

Simon Henry Gage, *The Life-History of the Toad*, Teachers' Leaflets, College of Agriculture, Cornell University.

A. H. Kirkland, The Habits, Food, and Economic Value of the American Toad, *Bulletin No. 46*, Hatch Experiment Station, Massachusetts Agricultural College.

A. H. Kirkland, The Usefulness of the American Toad, *Farmers' Bulletin No. 196*, United States Department of Agriculture.

CHAPTER XXVII. REPTILES

Suggestions to Teachers

The authors have not been in the habit of having their pupils dissect a lizard, but have contented themselves with a study of the living animal, supplemented by a short discussion by the teacher on important points of structure. In the *General Zoölogy*, however, the pine-lizard (*Sceloporus*) is dissected. If it is desired to have the pupils dissect the lizard, it will be easy for

the teacher to make up laboratory directions on the plan of those already given.

Either the pine-lizard or the swift (*Anolis*), both from the southern states, may be used for this study. Living specimens may be obtained of dealers in aquarium-material and natural-history supplies. They may be kept in a glass aquarium-jar or insect breeding-cage, with sand in the bottom, and branches to crawl upon. They should be kept in a warm and sunny place, and may be fed with flies or with small pieces of raw meat.

If the order of the *General Zoölogy* is followed, the pupil should be able by this time to study the living lizard without detailed suggestions, and it is advised that this be required. Some suggestions for the pupils' study are given beyond, for those who prefer a different order of treatment. The pupil who has been required to make his study without special directions may find them useful for comparison after he has done his own work.

Snakes and tortoises are easily obtained, and are not difficult to keep alive in a terrarium, especially if the earth is deep enough to allow them to burrow beneath the surface. A satisfactory terrarium for reptiles and amphibians can be made of wood (though metal would be better) with glass sides and with a removable zinc pan, which should be eight or nine inches deep. If this pan be made with sloping sides, and supported at its edge half an inch above a shallow zinc pan forming a bottom, drainage may be secured. Holes bored in the supports will allow evaporation of water from the bottom pan. If care is taken not to use too much water, such a terrarium of wood, carefully made, will last a long time. A convenient size is two feet and a half long by one foot and a half wide by two feet high.

THE LIVING PINE-LIZARD

Compare the shape of the lizard's body with that of the frog. What body-divisions are apparent? What is the body-covering?

Study the lizard's method of locomotion, comparing it with the method of locomotion of the frog. What are the divisions of the limbs?

Are the colors of the lizard's body protective? Is there any variation in color? Try the effect of colored backgrounds. Does this cause color-changes? Does the lizard tend to resemble the background? Try the effect of warming the lizard in the hand, or by placing in the Wardian case; try stroking the back. Do these stimulations produce color-changes? Put lizards in a box from which light can be excluded. Examine in half an hour. What color is observed? Leave lizards in a dark box over night. Examine the next day. What color is observed?

Do you notice respiratory movements? What is the lizard's method of respiration?

Examine the eyes. Is a nictitating membrane present? Which eyelid is more constantly moved, the upper or the lower? Does the lizard depend much on the sense of sight?

Report on any other characteristics observed, with explanation if possible. Do you notice anything you do not understand?

Have your observations shown any evidence of intelligence on the part of the lizard?

THE LIVING TURTLE

Notice the shape of the turtle, the comparative size of the head and the rest of the body, the general character of the legs and tail, and how the head, neck, legs, and tail can be retracted within the shell.

The shell is composed of horny epidermal plates lying over bony dermal plates, the latter being fused in places with the bones of the endoskeleton. Identify the upper shell (*carapace*), the under shell (*plastron*), and the bridge on each side which unites plastron to carapace. The study of a prepared specimen will make clear the relation of the epidermal and dermal plates to the bones of the endoskeleton. Describe the body-covering.

Note the coloration. Considering the habitat of the turtle, is it likely that the colors are protective? Note especially the color-markings of the head. What are the turtle's possible enemies?

Study the method of locomotion on land and in the water. Does it walk or crawl on land? What is the turtle's rate of progression on land? Is it greater or less in the water? Are there any special modifications of the structure of the feet which fit the turtle for locomotion in the water?

If possible, determine how the turtle breathes. Watch the animal closely for several moments.

Have you had evidence so far that the turtle can see well? Can it hear? If you are familiar with turtles in their habitat, you may be able to decide whether the animal depends on sight or hearing to warn it of approaching danger. Was there anything in the course of your study of the turtle to enable you to answer this question? By threatening the turtle with some object, such as a pencil, you may be able to observe the nictitating membrane.

If possible, feed the turtle or try to get it to seize upon a pencil. Report upon the method of taking food. Note the character of the jaws.

From your observations so far, do you consider the turtle an intelligent animal?

THE LIVING SNAKE

Make a study of the living snake, comparing it with the other back-boned animals you have studied. The following outline may be found useful:

General appearance.	Locomotion.
Divisions of the body.	Respiration.
Color, whether protective or not.	Organs of sense.
Enemies.	Method of obtaining food.

Place the snake in an empty aquarium-jar or other receptacle too deep for it to escape from, and study its efforts to escape.

Place the snake's head just over the edge of the jar, and see if with this purchase the snake can draw its body up. Determine what proportion of the length of the snake's body it is necessary to place on the edge of the jar in order to draw the whole body out of the jar. Describe the method of escape.

Examine the cast skin of a snake. Do the colors show? Examine particularly the head. Describe.

Additional Topics for Study

Compare the external structure of the box-tortoise with that of some species of mud-turtle. What characteristics seem to be related to the different habitats of the two animals?

Report on the economic importance and methods of capture of the green turtle and the hawkbill.

After having familiarized yourself with the great groups into which reptiles are divided, visit the reptile-house at a zoölogical park, to study further the external characters of the members of the different groups. Make a list of the most important species observed, arranging them under the proper group.

Other topics for study at a zoölogical park: the poisonous snakes of the Old and the New World; the reptiles of your state; alligators and crocodiles.

For the geological development of reptiles, consult:

Frederic A. Lucas, The Greatest Flying Creature, the Great Pterodactyl, Ornithostoma, *Report of Smithsonian Institution for 1901.*

Frederic A. Lucas, *Animals before Man in North America*, Chapters VI and VIII.

Frederic A. Lucas, *Animals of the Past*, Chapter VI.

Professor E. Ray Lancaster, *Prehistoric Animals*, Chapter V.

Consult the following references for the intelligence of reptiles: The Formation of Habits in the Turtle, by Robert Mearns Yerkes, in *Popular Science Monthly*, Vol. LVIII, No. 5, March, 1901; and Habits of the Box-Tortoise, by A. G. Mayer, in *Popular Science Monthly*, Vol. XXXVIII, No. 1, November, 1890.

CHAPTERS XXVIII AND XXIX. BIRDS

Suggestions to Teachers

Birds offer abundant material for out-of-door study by young pupils, and the opportunity thus presented should not be neglected by teachers of zoölogy. The most favorable season for taking up the study of birds in the field is undoubtedly during the spring migration, but it will be found quite possible to arouse an interest in bird-study out-of-doors at other seasons, if the teacher is himself interested and will arrange to accompany pupils on field-excursions. Opera-glasses or field-glasses will be found almost indispensable. When interest has once been aroused, the pupils should be encouraged to keep a bird-calendar, on which should be noted the time of arrival and departure of migrants, together with other facts of interest. If this is made a class project, the observations of each pupil will be available for the information of other members of the class. Suggestions for the study of birds out-of-doors will be found in Chapman's *Handbook of Birds of Eastern North America*, Chapter II.

In favorable localities the pupils should be encouraged to provide bird-houses for our native song-birds. See Lange's *Our Native Birds*, Blanchan's *How to Attract the Birds*, and Hodge's Nature Study Leaflet on *Our Common Birds*.

In some schools it has been found possible to keep pigeons alive for study. The opportunities afforded by zoölogical parks should not be overlooked. Use should be made wherever available of the museum specimens of birds mounted amid correct reproductions of their environment and illustrating important points in the life-history and habits of the species. The American Museum of Natural History in New York City is particularly rich in such collections.

The house-sparrow of Europe has become so common in the cities and towns of the eastern United States that it has been chosen to introduce the pupil to the study of birds in the following pages. This work might well follow a field-excursion with the teacher, where the emphasis would naturally be laid on identification and general observation of our native birds rather than on detailed study of the habits of any one species.

THE LIVING HOUSE-SPARROW

In the street, parks, or other locality where the birds abound, study the house-sparrow.

The house-sparrow was introduced into America from Europe, where it has long frequented the habitations of man. The males may be distinguished from the females by the black patch of feathers on the breast.

Do you notice any difference between the male and female other than that stated above?

How is the shape of the body adapted to locomotion in the air?

Considering the original environment of the house-sparrow (in fields and low shrubbery), do you consider that its colors are protective?

What methods of locomotion has the sparrow? Is the tail used in flight?

Have you any evidence that the sparrow hears? Does it see well?

What is the food of the sparrow?

In its present environment has the sparrow any enemies among other animals? What conditions are unfavorable to the young or adult?

Is the sparrow sociable or solitary in its habits? If other birds are found with it, note its behavior toward them.

Has the sparrow a song? Are you able to interpret any of the call-notes so as to tell what they mean?

What mental traits do you observe?

If possible, find and describe the nest and eggs. Have you any knowledge as to number of broods produced during the season? When is the nest built?

Do you know any other bird which frequents city streets? To what qualities do you think the sparrow's successful occupation of our streets is due?

EXTERNAL STRUCTURE OF THE PIGEON

The body-covering. Note the character of the body-covering of the pigeon, especially the way in which the parts overlap, forming a close, firm covering.

Pull out and study one of the large wing-feathers.. Note the expanded portion, the *vane*, supported on the hollow *quill* and strengthened by a central axis, the *shaft*. On each side of the shaft are the *barbs*, from which branch still smaller structures, the *barbules*.

Examine the barbules with a low-power objective.

Study and describe the way in which these parts are related to each other.

Study and describe briefly the structure of one of the *body-* or *contour-feathers*, comparing it with one of the large tail-feathers.

In a similar way, examine a fluffy *down-feather* picked from among the larger feathers on the breast; also a hair-like feather (*filoplume*) from the same region.

Are the feathers equally distributed over the body? Discuss the advantages of feathers as a body-covering.

Sketch the different kinds of feathers, labeling the parts shown.

The head. Identify *upper* and *lower mandible*. Is the upper mandible movable?

Compare the structure and function of the tongue of the pigeon and the frog. Notice the *glottis* directly behind the

tongue. By means of a probe, discover where the *nostrils* open into the mouth. Notice the fleshy *cere* at the base of the beak where the nostrils open. Find the *third eyelid.* Locate the external opening of the ears. How are the feathers modified in that region?

The trunk and its appendages. In the legs identify *thigh, lower leg,* and *foot.* The foot of the pigeon is composed of several fused bones, which were separated in the young bird. These bones belong to both the ankle and the foot region; hence the foot is really a *tarso-metatarsus.* What is the covering of the foot? How are the toes arranged? For what is the foot adapted?

In the wings make out divisions into *upper arm, forearm,* and *hand.* The long feathers on the hand are called *primaries;* on the forearm, *secondaries;* on the upper arm, *tertiaries.* By bending the wing at the different joints, make out how many large feathers are borne on each division of the wing.

Extend the wing, and by raising and lowering it study its action in flight. Blow against the lower surface at right angles when the wing is extended; against the upper surface. Note the effect on the feathers in each case. Notice the position of the feathers when the wing is quickly raised.

Find the *oil-gland* in the median line among the feathers covering the upper surface of the base of the tail. Press it with the forceps to see the oil used by the pigeon for preening its feathers.

INTERNAL ANATOMY OF THE PIGEON

Insert a tube into the mouth and inflate the *crop,* compressing the neck to prevent escape of air. Insert the tube into the *glottis* and inflate the *lungs.* Note the effect, and explain. Break the humerus and push its broken end out through the flesh. Attach a rubber tube to the end nearest the body and inflate. Explain what you observe.

Cut through the abdominal wall just posterior to the breast-bone and around on each side through the ribs and the coracoid

bone till the entire breast can be removed. Remove the skin from the neck to distinguish the *œsophagus* and *trachea*.

Identify the *mouth, œsophagus, crop, stomach, gizzard, intestine, cloaca, pancreas,* and *liver*. Make a drawing (natural size) showing each of the organs already mentioned as nearly as possible in its natural position.

Remove the above-mentioned organs. Examine the contents of the crop and the gizzard.

Identify the *heart*, with the arteries and veins. Notice the thin sac, the *pericardium*, inclosing the heart. Identify the *auricles* and *ventricles*. Examine the lungs, noting that they are closely attached to the back. Add these organs to your drawing or make a separate drawing showing them.

In the posterior portion of the body-cavity are the *kidneys*, composed of several lobes. Draw in position and remove. Observe the white *nerves* extending from the spinal column and passing to the thighs.

Just in front of the kidneys are the reproductive organs, two white oval *testes* in the male; in the female, the *ovary*, often showing eggs in process of development. Make a drawing.

The brain may be studied as directed in the frog. If studied, make a drawing (× 2), naming the parts.

Additional Topics for Study

Visit the collection of living birds at a zoölogical park for study of the characteristics of the great bird-groups. Make a list of the bird-groups, or take your *General Zoölogy* with you. Make a special study on one trip of the water-birds; at another time study the land-birds. Notice how, with the variety of bird-forms, the essential characteristics used to classify birds reappear in all the individual cases observed. Are any birds seen which do not fall into one of the groups named? Make a list of the most striking species seen, classifying them properly.

Other topics for study at a zoölogical park: sexual differences in birds; special characteristics of the owls, hawks, eagles, and vultures; identification of birds found in your home region; special study of the ostriches, emus, cassowaries (*Struthiones*); modifications of the beak in birds; modifications of the legs and feet of birds.

For the migration of birds, their geological development, and economic importance, consult the following references:

Frank M. Chapman, The Nocturnal Migrations of Birds, *Popular Science Monthly*, Vol. LXV, No. 4, August, 1894.

Professor W. K. Brooks, Migration, *Popular Science Monthly*, Vol. LII, No. 6, April, 1898.

Dr. F. H. Knowlton, The Journeyings of Birds, *Popular Science Monthly*, Vol. LX, No. 4, February, 1902.

C. C. Trowbridge, Wind and Bird Migration, *American Naturalist*, Vol. XXXVI, September, 1902, p. 735.

Frederic A. Lucas, *Animals before Man in North America*, Chapter VII.

Frederic A. Lucas, *Animals of the Past*, Chapters V and VIII.

A Review of Economic Ornithology, in the *Yearbook*, United States Department of Agriculture, 1899.

Edward Howe Forbush, Two Years with the Birds on a Farm, *Fiftieth Annual Report of the Massachusetts State Board of Agriculture.*

Walter B. Barrows, The English Sparrow (*Passer domesticus*) in North America, *Bulletin No. 1*, United States Department of Agriculture, Division of Economic Ornithology and Mammalogy.

Sylvester D. Judd, Birds of a Maryland Farm, a Local Study of Economic Ornithology, *Bulletin No. 17*, United States Department of Agriculture, Division of Biological Survey.

The Common Crow of the United States, *Bulletin No. 6*, United States Department of Agriculture, Division of Biological Survey.

The Relation of Sparrows to Agriculture, *Bulletin No. 15*, United States Department of Agriculture, Division of Biological Survey.

Choose some bird of your home region in which you have become specially interested, and look up information concerning it in the following references. Arrange your notes in the form of a short life-history of the species. Consult the following:

A. Radclyffe Dugmore, *Bird Homes.*

F. H. Herrick, *The Home Life of Wild Birds.*

H. E. Minot, *Land and Game Birds of New England.*
F. M. Chapman, *Handbook of Birds of Eastern North America.*
W. E. D. Scott, *Bird Studies.*
F. Schuyler Mathews, *Field Book of Wild Birds and their Music.*
W. A. Stearns, *New England Bird Life* (edited by Dr. Elliott Coues).
Ralph Hoffmann, *A Guide to the Birds of New England and Eastern New York.*

For information concerning bird-protection in the United States, consult the last *Annual Report of the National Association of Audubon Societies*, and the *Report of the Committee of the American Ornithologists' Union on the Protection of North American Birds.*

Examine the current number of *Bird-Lore*, and report upon what you consider to be the most interesting article in the issue.

For the question of the intelligence of birds, consult C. F. Hodge, The Method of Homing Pigeons, in *Popular Science Monthly*, Vol. XLIV, No. 6, April, 1894. Also read Legislation for the Protection of Birds other than Game-Birds, *Bulletin No. 12*, United States Department of Agriculture, Division of Biological Survey.

CHAPTERS XXX AND XXXI. MAMMALS

Suggestions to Teachers

The gray squirrel has been chosen as a subject for study in the field since it has been introduced into parks in several cities of the eastern United States, where it offers excellent opportunities for observation of its external structure and many of its habits and traits of character. In country districts the red squirrel or the chipmunk would probably be more useful. The little white-footed or deer-mouse has been kept in captivity in some schools for similar study. Domestic rabbits and guinea-pigs have long been used; cats, dogs, and horses are everywhere available. While it is not always possible to observe mammals in the field, opportunities are offered by some of the large

museums for the study of mammals mounted amid correct reproductions of their environment.

No directions have been written for the study of the internal anatomy of mammals, but for a teacher who desires it, it will be possible to make up directions for study on the plan already given. For study of mammalian organs, use leg-joints of the sheep, the heart, lungs, liver, and kidneys of the sheep or the calf, the head and brain of the sheep, and the eye of the calf. These can all be furnished by the local butcher.

THE LIVING GRAY SQUIRREL

Take a few pieces of raw meat, nuts, and fruit with you and go to a public park to study the gray squirrels. If you have a camera, take it with you and get photographs of the squirrel in various attitudes to illustrate your study. Sketches of the squirrel will also be useful, if you have no camera.

Before beginning this study familiarize yourself with the structure of the squirrel's skull and teeth, either from a specimen or from the figure in the *General Zoölogy*. Identify the chisel-shaped front teeth (*incisors*) and the grinding-teeth (*molars* and *premolars*). There are two premolars in the upper jaw and three in the lower jaw, the other grinding-teeth being molars. Study the structure of the teeth, noticing especially the cutting-edges of the incisors.

Notice the space between the molars and incisors. Examine also the surfaces on the skull where the lower jaw is articulated, and the protuberances (*condyles*) on the lower jaw at this place. Do the condyles extend longitudinally with the long diameter of the skull or transversely to it?

What is the general form of the body? What divisions are apparent?

What is the body-covering? Is the color protective?

Study the activities of the squirrel and the adaptation of the body-form to the life of the animal. What different postures

does the squirrel assume? What are the methods of locomotion? For what purposes does the squirrel use its hind legs? its front legs? What is the use of the *vibrissæ*, — the "whiskers" about the mouth?

On what senses does the squirrel seem to depend for its general knowledge of its environment? Can it see well at any distance? Is it alert to sounds? Has it any special means of defense?

Test squirrels to see what kind of food they prefer. Study the method of holding food and of eating. Explain how the structure of the skull and teeth adapts them to the work they have to do. What does the squirrel do with food that it does not immediately eat?

What mental characteristics have you noticed in the course of your study? Is the squirrel timid, suspicious, jealous, curious? Make a list of the mental attributes which you observe. Have you noticed any special exhibition of intelligence? Classify the activities you have observed as instinctive or intelligent. What is the squirrel's attitude toward other squirrels?

If possible, find and describe the nest, a bulky affair of leaves in the top of a tree. Do you know, from previous observation, at what season or seasons the squirrel occupies this nest?

Add any other observations you may consider of interest, whether made at this time or in the past. Consider how much you know of the life of the squirrel in its natural habitat. Are squirrels solitary or social? On what do they feed at different seasons of the year? Where do they spend the winter? When are young produced, and how many? How long are they cared for? What are their enemies, and what means of protection or defense have they? Are squirrels economically important? What harm is done by squirrels? Do they do any good? Name any habits acquired during life in the park. What effect has residence in the park had on the squirrel's character? Why are squirrels allowed to live unmolested in the park? Do you think

of any damage they could do? Have you any evidence that they are more numerous in the park than in an equal area in their natural habitat? How can you account for the fact?

Consult the following references for the habits of the gray squirrel which you are unable to study yourself. Arrange your notes as far as possible in the form of a short life-history of the squirrel.

C. H. Merriam, *Mammals of the Adirondack Region.*
John Burroughs, *Squirrels and Other Fur-Bearers.*
W. Stone and W. E. Cram, *American Animals.*
E. Ingersoll, *Wild Neighbors.*

THE LIVING RABBIT

Study the living rabbit from a tame specimen, comparing it with the squirrel. Use the suggestions given for the study of the squirrel as far as they may be applied.

Note especially the cleft upper lip, and its use in feeding.

Consider what you know of the habits of the wild rabbits of your region, and add these statements to your paper.

At the close of the paper make a list of the most important structural differences between the rabbit and the squirrel. What similarities do you observe in their structure? What differences in habits do you notice? Which animal seems to you to be the more intelligent? Why?

THE DOMESTIC HORSE

Compare the external structure of the horse with that of the squirrel or rabbit, and man, noting points of resemblance and difference. Identify especially the elbow in the fore leg and the knee in the hind leg. Discuss the different arrangement of the digits of the legs.

Make observations on horses in movement, to determine the order in which the feet are used (1) in walking, (2) in trotting, (3) in galloping; how a horse lies down; how it gets up; how

it takes hold of its food (not in a feed-bag); how its teeth are arranged; the extent to which the loss of the tail may be a disadvantage.

What is there in the structure of the toe that makes shoeing a horse a necessity on hard streets? (Lift up a horse's front foot and observe.)

What have you ever done, or seen done, to prevent cruelty to horses?

Have you any suggestions to offer as to what drivers and teamsters and stablemen should not be permitted to do with horses in their care?

Visit a museum of natural history to study the geological development of the horse. How far back has the ancestry of the horse been traced? To what form? What was the size of the animal, and where did it live? What changes in structure have occurred to produce the horse of to-day?

If specimens are not on exhibition to answer the questions on the evolution and ancestry of the horse, consult the following:

William D. Matthew, The Evolution of the Horse, *Guide Leaflet No. 9*, American Museum of Natural History.

Frederic A. Lucas, *Animals of the Past*, Chapter IX.

N. S. Shaler, The Horse, *Domestic Animals*.

THE SKULL OF THE CAT

Note the general shape of the skull. The bones inclosing the brain form the *cranium*, anterior to which are the bones of the face. The bones of the upper jaw are immovably fixed; those of the lower jaw are articulated to the rest of the skull by means of two protuberances which fit into corresponding surfaces on the cranium.

Note the *sutures*, or lines, which separate the bones. As the animal grows, these sutures tend to become obliterated by the fusion of the bones. Through an opening at the posterior end

the spinal cord enters the cranium; above the opening is a prominent ridge for the attachment of muscles. On either side of the opening are the *occipital condyles*, which articulate with the first vertebra of the spinal column. The rounded protuberances on the ventral surface of the cranium inclose the middle ear. Find the external opening of the ears just anterior to these protuberances. At the front end of the skull are the anterior *nasal apertures*. The nostrils open posteriorly into the pharynx. Identify the posterior nostrils. The orbits or cavities for the eyes are situated on the sides of the skull. Each orbit is bounded exteriorly by a prominent ridge. Find the opening through which the optic nerve enters the cranium. Several other openings in the skull will also be found through which nerves pass from the brain.

Identify the kinds of teeth. The small, sharp teeth in the front of each jaw are the *incisors*, or cutting-teeth; then come the longer *canines*, followed by the *premolars* (three on each side of the upper jaw and two on each side of the lower jaw). In an adult cat one *molar* tooth will be found on each side of each jaw. The lower molars are especially large and act against the second premolar of the upper jaw. What do you consider the function of each kind of teeth? Use the initials to designate the teeth, and place the number of teeth on one side of the upper jaw above the line, and the number on one side of the lower jaw below the line, making the dental formula as follows:

$$\frac{\ldots\ldots i. \quad \ldots\ldots c. \quad \ldots\ldots pm. \quad \ldots\ldots m.}{\ldots\ldots i. \quad \ldots\ldots c. \quad \ldots\ldots pm. \quad \ldots\ldots m.}$$

Identify the same teeth when present in the other skulls furnished, and make out a dental formula like the above for each animal. Discuss the function of the teeth in each case, as determined by what you know of the habits of the animal in connection with what you have observed of the structure of the teeth.

THE PRIMATES

Visit a zoölogical park or a museum of natural history to study the Primates. For the special object of this study, see the last paragraph of these suggestions. Identify at least the following: lemurs, marmosets, howlers, baboons, macaques, the orang-utan, chimpanzee, and gorilla.

In the lemurs (*Lemuridæ*) notice the thick, woolly coat and the large eyes. Most of the lemurs are nocturnal in their habits. In what regions are they found? They differ quite widely in structure from other Primates.

The rest of the Primates (including man) are classified in two groups, depending on the character of the septum (partition) between the nostrils. One group contains all the monkeys with a broad internasal septum, so that the nostrils open forward; the other includes Primates with a narrow internasal septum, with the nostrils opening downward. Arrange your notes of the Primates studied under the appropriate heading. Examine a number of specimens to see if this distinction has a geographical basis,— that is, whether it is possible to say that all monkeys with a broad internasal septum belong to one hemisphere, and that those with a narrow septum belong to the other. To which division does man belong?

Examine the marmosets (*Hapalidæ*). What is the character of the body-covering? What is the character of the tail, if present? Is it long or short? hairy or naked? Is it used as an organ of prehension? Can the thumb be opposed to the other fingers? Can the great toe be opposed to the other toes? Do the animals maintain an upright or nearly upright position, or do they walk on "all fours" like a dog or cat? Notice the character of the terminal appendage of the fingers and toes. Is it in the form of a flat nail, or a claw, or both? Where are marmosets found?

Similar questions should be answered regarding the howlers, and the monkeys which belong to the genus *Cebus*, all included in the family *Cebidæ*.

The macaques, baboons, and their allies (*Cercopithecidæ*) may be separated from the family which includes the orang-utan, the chimpanzee, and the gorilla (*Simiidæ*) by the presence or absence of a tail and by the relative length of the arms and legs. After examining various specimens, decide exactly how you would express these differences. Do you notice any other peculiarity which seems to characterize one or the other family? Look up the geographical distribution of the three members of the *Simiidæ*. How can you tell these three Primates apart?

Man belongs to the family *Hominidæ*. Keeping in mind the characters which have been useful in classifying the Primates, give those which you would use to separate the Hominidæ from the other members of the order.

Take your notes home and work them up into the paper suggested below.

The special object of this study is to help you to discover the characteristics which are used in the classification of this group of animals. Try to fix your attention first on the characteristics which reappear in all the members of a family, ignoring the specific differences which occur. Make a list of the families as taken up in this paper, arranging, as already suggested, all the families with the exception of the *Lemuridæ* under the proper caption of monkeys with a broad nasal septum or monkeys with a narrow nasal septum. State the geographical distribution of these two groups. Write beneath the family the characteristics which you have discovered to separate the members of that family from other families. Write the names of the species studied in each family, with short notes on their external appearance and geographical distribution.

MAN

If you have made the suggested study of the Primates at a zoölogical park or museum, you will be able to answer the first two questions from the observations made in that work.

What other animals are most nearly related to man? Where are they found?

What structural characteristics serve to separate man from these animals?

What psychological attributes does man possess in common with the lower animals? How does he differ from them? Consult the *Report of Smithsonian Institution for 1901*, The Mind of Primitive Man, by Franz Boas.

Study the mental attributes of monkeys at a zoölogical park, comparing the monkeys' actions with those of a child. What similarities do you notice? What differences?

How many species of man are there? How many races of man? Describe briefly the different races of man, with notes on their anatomical differences, their geological distribution, and their state of culture.

Make a special study of the habits of some low savage people. Consult the *Report of Smithsonian Institution for 1902*, The Pygmies of the Great Congo Forest, by Sir Harry H. Johnston; also *Report of Smithsonian Institution for 1902*, The Wild Tribes of the Malay Peninsula, by W. W. Skeat.

What is meant by "the missing link"? What is *Pithecanthropus?*

Study the geological distribution of man. When did man first appear on the earth? Where? What evidences of early man have been discovered? Through what stages has man passed from early time till to-day?

What natural means of defense has man? Has he been successful in the struggle for existence? Give some reasons for his success or failure. Is man subject to natural selection?

Additional Topics for Study

What articles of human use are made of fur?

Study the tracks made by different animals after a snow-storm. Describe how you can distinguish the tracks made by the different animals you have observed, and show the differences by sketches.

What important structural resemblances are there between fishes, amphibians, reptiles, birds, and mammals?

What are the principal structural differences between a squirrel and a locust? What important resemblances?

Visit a zoölogical park to fix the characters used to classify mammals. Take your *General Zoölogy* with you. Visit the different houses in which the mammals are placed and make a list of these mammals, classifying them as well as possible under the different groups to which they belong.

Other topics for study at a zoölogical park: the hoofed mammals; the prairie-dog; wolves, foxes, and dogs; the lion, tiger, leopard, and jaguar.

Arrange a sheet of paper as below, and write the differences between the different classes of Vertebrates under the appropriate heading:

	Fishes	Amphibians	Reptiles	Birds	Mammals
Body-covering					
Temperature					
Respiration					
Reproduction					
Appendages					

Make a comparative study of the skeleton in the five classes of Vertebrates. What similarity of plan is there in all the classes? What differences in the appendages in the different classes?

Consult some of the following references for the question of the intelligence of monkeys:

Dr. Alfred E. Brehm, The Ways of Monkeys, *Popular Science Monthly*, Vol. XXVII, No. 2, June, 1885.

David Starr Jordan, The Story of Bob, *Popular Science Monthly*, Vol. XLIV, No. 2, December, 1893.

M. J. Fischer, My Monkeys, *Popular Science Monthly*, Vol. XXV, No. 4, August, 1884.

S. S. Buckman, Babies and Monkeys, *Popular Science Monthly*, Vol. XLVI, No. 3, January, 1895.

Edward L. Thorndike, The Intelligence of Monkeys, *Popular Science Monthly*, Vol. LIV, No. 3, July, 1901.

Consult the following references for the general question of instinct and intelligence in the animal kingdom:

C. Lloyd Morgan, *Animal Behavior*.

G. J. Romanes, *Animal Intelligence*.

G. J. Romanes, *Mental Evolution in Animals*.

Wesley Mills, *The Nature and Development of Animal Intelligence*.

W. H. Larrabee, The Intelligence of Cats, *Popular Science Monthly*, Vol. XXXVIII, No. 3, January, 1891.

Edward L. Thorndike, Some Experiments on Animal Intelligence, *Science*, Vol. VII, pp. 818–824.

Edward L. Thorndike, Do Animals Reason?, *Popular Science Monthly*, Vol. LV, No. 4, August, 1899.

Edward L. Thorndike, The Evolution of the Human Intellect, *Popular Science Monthly*, Vol. LX, No. 1, November, 1901.

Douglas A. Spalding, Instinct, *Popular Science Monthly*, Vol. LXI, No. 2, June, 1902.

John Burroughs, Do Animals Think?, *Harpers*, February, 1905.

John Burroughs, What do Animals Think?, *Century*, August, 1904.

For information regarding the fur seal, consult *Fur Seal and Other Fisheries of Alaska*, and other publications on this topic by the United States government.

For information concerning North American ruminants, consult *Guide Leaflet No. 5*, American Museum of Natural History, by J. A. Allen.

For the ancestry of the domestic cat and dog, consult *Mostly Mammals*, by R. Lydekker, pp. 188, 197; and The Dog, in *Domesticated Animals*, by N. S. Shaler.

For the social and domestic life of animals, consult *Study of Animal Life*, Chapters V and VI, by J. Arthur Thomson.

Read The Okapi; the Newly Discovered Beast living in Central Africa, by Sir Harry H. Johnston, *Report of Smithsonian Institution for 1901.*

Consult the Craniology of Man and Anthropoid Apes, by N. C. MacNamara, in *Report of Smithsonian Institution for 1902.*

For information concerning the activities of the United States Department of Agriculture, Bureau of Animal Industry, consult the last annual report of the Bureau.

For the geological development of mammals, and for information concerning the early history of man on the earth, consult:

Frederic A. Lucas, *Animals before Man in North America*, Chapters VII, IX, and X.

Frederic A. Lucas, *Animals of the Past*, Chapters X and XI.

Professor E. Ray Lancaster, *Prehistoric Animals*, Chapters II, III, and IV.

Professor G. F. Wright, Man and the Glacial Period, *Popular Science Monthly*, Vol. XXXIX, No. 3, July, 1891.

W. H. Larrabee, Cave Dwellings of Man, *Popular Science Monthly*, Vol. XLI, No. 1, May, 1892.

Professor E. P. Evans, Pithecoid Man, *Popular Science Monthly*, Vol. XLVI, No. 2, December, 1894.

Dr. Charles C. Abbott, The Antiquity of Man in North America, *Popular Science Monthly*, Vol. LV, No. 3, July, 1899.

Professor A. S. Packard, An Afternoon at Chelles and the Earliest Evidence of Human Industry in France, *Popular Science Monthly*, Vol. LXI, No. 1, May, 1902.

A book which covers the whole subject in a simple way is *The Story of Primitive Man*, by Edward Clodd.

CHAPTER XXXII

THE HISTORICAL DEVELOPMENT OF ZOÖLOGY

Consult an encyclopedia or some of the following references for further information concerning some of the naturalists mentioned in Chapter XXXII.

Professor William A. Locy, Malpighi, Swammerdam, and Leeuwenhoek, *Popular Science Monthly*, Vol. LVIII, No. 6, April, 1901.

Professor W. K. Brooks, An Old Naturalist, Conrad Gesner, *Popular Science Monthly*, Vol. XLVII, No. 1, May, 1895.

President David Starr Jordan, Agassiz at Penikese, *Popular Science Monthly*, Vol. XL, No. 6, April, 1892.

Professor Angelo Heilprin, A Student's Recollections of Huxley, *Popular Science Monthly*, Vol. XLVIII, No. 3, January, 1896.

Professor William Henry Hudson, Herbert Spencer, the Man and his Work, *Popular Science Monthly*, Vol. L, No. 4, February, 1897.

Grant Allen, Spencer and Darwin, *Popular Science Monthly*, Vol. L, No. 6, April, 1897.

Professor W. H. Doll, Lamarck, the Founder of Evolution, *Popular Science Monthly*, Vol. LX, No. 3, January, 1902.

Further information will be found in *A Short History of Natural Science*, by Arabella B. Buckley; and *A History of Science*, by Henry Smith Williams.

MISCELLANEOUS GENERAL TOPICS FOR STUDY

For suggestions as to work with a camera in zoölogy, consult *Nature and the Camera*, by A. Radclyffe Dugmore; *Wild Life near Home; How to Study and Photograph It*, by R. Kearton; *Bird Studies with a Camera*, by Frank M. Chapman.

For information concerning the United States National Museum, consult an article under that heading in the *Popular Science Monthly*, Vol. LV, No. 4, for August, 1899.

For information concerning the Smithsonian Institution, see article under that heading by Professor H. Carrington Bolton, in

Popular Science Monthly, Vol. XLVIII, Nos. 3 and 4, January and February, 1896.

For information on the American Museum of Natural History, consult the *American Museum Journal* and the *Guide Leaflets*, issued as supplements to the *Journal*.

For information concerning the New York Zoölogical Park and the New York Aquarium, consult the *Bulletin*, published by the New York Zoölogical Society.

Read the article on The New York Aquarium, by Professor Charles L. Bristol, in the *Popular Science Monthly*, Vol. LVIII, No. 4, February, 1901.

For information concerning the National Zoölogical Park, consult *Report of Smithsonian Institution for 1901*, The National Zoo at Washington, by Ernest Thompson Seton, or article by same author in the *Century*, March to May, 1900.

Examine the current issue of the *Popular Science Monthly* and report upon any article which touches upon your work in zoölogy.

For the geographical distribution of animals in the United States, consult *Bulletin No. 10*, United States Department of Agriculture, Division of Biological Survey, Life Zones and Crop Zones, by C. Hart Merriam.

If specimens are available, make a study at a museum of natural history of the geological development of animals, studying the fossils shown in order from the Age of Invertebrates to the Age of Man.

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